IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF MASSACHUSETTS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Plaintiff, v. HARMAN INTERNATIONAL INDUSTRIES, INCORPORATED, Defendant.	Civil Action No.: 05-10990 DPW Magistrate Judge Judith G. Dein

MIT'S OPENING MEMORANDUM
ON CLAIM CONSTRUCTION

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I. INTRODUCTION

Automobile navigation systems are becoming ubiquitous in modern automobiles. Automobile manufacturers offer navigation systems as standard features or as an option on new vehicles. After-market navigation systems are sold for automobiles that do not have them installed. Hand-held navigation systems are now cheaply and readily available.

Common to all of these is that the driver tells the system the destination (through a "driver interface"), and a "computer processor" then determines the route to the destination using a "map database" and information the system learns from position sensors, such as a GPS receiver, about the automobile's current position. The system then speaks the directions at the appropriate time and place along the route in order to direct the driver to her desired destination.

Two people, Chris Schmandt and Jim Davis, working at the MIT Media Lab in the late 1980s, invented the first *operational* automobile navigation system that could provide intelligent, understandable spoken driving directions in real time -- what they called an electronic "Back Seat Driver." The invention was the subject of Davis' MIT Ph.D thesis, and has been acknowledged by experts in the field as a real break-though, being selected for presentation at the first major automobile navigation conference by no other than Harman's technical expert, who as one of the conference chairs, thought the idea was "fresh" and "different."

In this case, Harman International Industries, Inc.'s ("Harman") products are accused of infringing the claims of MIT's patent. Pursuant to the Court's March 26, 2007 scheduling order (DI 123), Massachusetts Institute of Technology ("MIT") submits this memorandum on claim construction for U.S. Patent No. 5,177,685 ("the '685 patent").

II. SUMMARY OF THE ISSUES

Claim 1

Claim 1 is the one independent claim in the case.[1]

It reads (with the terms in dispute *italicized*, and with a more simple description of each term provided after each paragraph in [brackets]):

> An automobile navigation system which produces spoken instructions to direct a driver of an automobile to a destination in real time comprising:
>
> computing apparatus for running and coordinating system processes [the microprocessor that controls the process],
>
> *driver input means functionally connected to said computing apparatus for entering data into said computing apparatus*, said data including a desired destination [the touch-screen or "keypad" for entering the destination] ,
>
> a *map database* functionally connected to said computing apparatus *which distinguishes between physical and legal connectivity* [a map database which knows whether two roads connect and whether turns are legal or not],
>
> position sensing apparatus installed in the automobile and functionally connected to said computing apparatus for providing said computing apparatus data for determining the automobile's current position [a GPS receiver or other position sensor],
>
> a location system functionally connected to said computing apparatus for accepting data from said position sensing apparatus, *for consulting said map database*, and for determining the automobile's current position relative to the map database [a software module within the system that takes the GPS or position coordinates, and maps them to the map database, so the system would know where you are on the route],

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[1] Claims may be written in "independent" or "dependent" form. A claim is in "independent" form if the claim does not refer to another claim. See 35 U.S.C. § 112, ¶ 3. A claim is in "dependent" form, when, as a matter of drafting shorthand, it incorporates all of the limitations of claims from which it "depends," as set forth in 35 U.S.C. § 112, ¶ 4:

> [A] claim in dependent form shall contain a reference to a claim previously set forth and then specify a further limitation of the subject matter claimed. A claim in dependent form shall be construed to incorporate by reference all limitations of the claim to which it refers.

> a route-finder functionally connected to said computing apparatus, for accepting the desired destination from said driver input means and the current position from said location system, for consulting said map database, and for computing a route to the destination [a software module that calculates your route],
>
> *a discourse generator* functionally connected to said computing apparatus for accepting the current position from said location system and the route from said route finder, for consulting said map database, and for composing discourse including instructions and other messages for directing the driver to the destination from the current position [a software module that takes the route, and determines what should be said to the driver, and when],
>
> a speech generator functionally connected to said discourse generator for generating speech from said discourse provided by said discourse generator [the software module that takes the output from the discourse generator, and generates electronic signals to create speech for the driver to hear], and
>
> voice apparatus functionally connected to said speech generator for communicating said speech provided by said speech generator to said driver [the speakers in the car that take the electronic signal from the speech generator, and create the sound the driver hears].

Claim 45 reads:

> The automobile navigation system of claim 1 wherein said discourse generated comprises a long description of an act given substantially before the act is to be performed and a short description given *at the time the act is to be performed*. [The "long description" tells you to "prepare to turn right in 1 mile." The "short description given at the time the act is to be performed," tells the driver to "turn now."].

The terms the parties are asking the court to enter construction on, and a brief summary of the issues, are:

1) "*Discourse generator"*

The use of a "discourse generator," to generate the directions the user hears, is the heart of the invention and is what distinguishes the invention from anything done before. Although "discourse" has a special meaning in the field of computational linguistics, the term "discourse

generator" has no standard meaning, and therefore must be construed with reference to the patent. MIT proposes that the definition be taken *directly* from the patent --

> *Discourse generator*: a module, in software or hardware, which composes driving instructions and other messages <u>according to a discourse model</u>, for delivery at the appropriate time and place, and based on the current position of a vehicle and its planned route.
>
> *Discourse model*: a way to provide information needed by a conversation participant in context to enable the conversation participant to determine why an utterance was provided and what the utterance means.

Harman, on the other hand, seeks to define the term in an effort to write the inventive idea right out of the patent, so that the patent would cover the prior art. Thus, Harman proposes that the term simply mean -- *Discourse*: "instructions and other messages." Of course, this definition is not found anywhere in the patent.

2) "*driver input means* functionally connected to said computing apparatus *for entering data into said computing apparatus, said data including a desired destination*"

The patent broadly describes numerous ways for the driver to tell the system the desired destination -- including a computer keyboard, a telephone keypad, or speech input. Exh. 1 at 20:67-21:13; 23:62-24:60. How the data was input was not part of the invention, and the fact that the MIT patent discusses so many ways to do so underscores the inventors' belief that any data entry device would work.

Harman's position is that the claim must be narrowly construed to cover only the instance when the driver *types* the electronic destination data into the system, as opposed to selecting letters from a keypad or selecting a street from a list that causes data to be sent to the system to allow it to learn the destination. Of course, there is no limitation in the patent that supports such a narrow construction.

3) "*a map database* functionally connected to said computing apparatus *which distinguishes between physical and legal connectivity*"

The parties agree as to what "physical" and "legal" connectivity are. ("Physical" connectivity indicates whether two streets are connected. "Legal" connectivity indicates whether a vehicle is permitted legally to make a turn or enter a road.)

The dispute centers on what it means to "distinguish" between legal and physical connectivity. MIT believes the claim language is clear -- if the database (as the claims says, "a [single] database") *distinguishes* between, and thus provides, both physical and legal connectivity data, the claim covers it. Harman argues that "*a* map database" covered by the patent must in fact be *two* separate but equal databases, one representing physical, and the other legal, connectivity. Harman's definition would exclude the database described in the patent.

4) "a location system functionally connected to said computing apparatus for accepting data from said position sensing apparatus, *for consulting said map database,* and for determining the automobile's current position relative to the map database"

MIT believes the claim language is clear -- if the location system "consults" (which means uses, refers to, or relies on) the data in the database, it is using the invention. Harman seeks to limit the claim to require *direct* access or connection to the map database.

5) "a short description given *at the time the act is to be performed.*"

Finally, in claim 45, it is clear from the patent that the short description occurs in, on, or near the location on the route at which the act is to be performed, shortly before the driver is required to act. Harman seeks an incredibly narrow construction of this term that would make the patent not cover anything. Harman argues that the term should mean "at the instant the act is to be performed." Of course, in a driving system, the driver needs some reaction time -- but Harman argues for a construction that doesn't give the driver that reaction time. It eviscerates the claim.

* * *

Understanding the invention is essential to an accurate delineation of the patentee's right to exclude others from the field of his invention:

> Ultimately, the interpretation to be given a term can only be determined and confirmed with a full understanding of what the inventors actually invented and intended to envelop with the claim. The construction that stays true to the claim language and most naturally aligns with the patent's description of the invention will be, in the end, the correct construction.

Renishaw PLC v. Marposs Societa' Per Azioni, 158 F.3d 1243, 1250 (Fed. Cir. 1998) (citation omitted); *accord Phillips v. AWH Corp.*, 415 F.3d 1303, 1316 (Fed. Cir. 2005). As the court will see, MIT's positions focus on the *invention* and seek definitions that *exactly* describe the invention as described in the patent. MIT does not seek artificially constrained definitions carefully tailored to avoid infringement. Harman, on the other hand, completely ignores what the invention is, or its true scope, by arguing for definitions *contrary* to the patent-in-suit (see, for example, its argument regarding the terms "entering" or "inputting" the desired destination; "functionally connected"; "discourse generator"; and "at the time the act is to be performed"); seeking narrow definitions based solely on *illustrative* -- but non-limiting-- examples described in the patent-in-suit (e.g., "consulting said map database"); and arguing for narrow limitations based on statements taken out of the context of the invention (e.g., "which distinguishes between physical and legal connectivity").

To help the court understand the invention, a brief background of the technology follows.

III. BACKGROUND OF THE '685 PATENT

A. Early Automobile Navigation Systems Had Rudimentary Ways of Providing the Directions to the Driver

In the late 1980s, there was growing interest in the consumer electronics industry with the idea of providing a user-friendly in-vehicle navigation system. (The industry's first major Vehicular Navigation Conference occurred in 1989). Because this was a new area, there were no specialists -- and people were bringing whatever knowledge they had from prior work to this new arena. As a result, researchers were going off in different directions based on their own prior experience.

So, for example, some in the industry were working on the earliest map databases, figuring out the best way to provide map data to whoever might be able to use it -- but not necessarily for purposes of direction giving, because there were no commercial applications for that at the time. Others were working on using computers to generate better routes -- directions which would take into account things like road types and highway speeds, to provide the best route to a destination. Of course, these programs, using the slow computers of the time, also needed to be efficient so that the route could be generated while the user waited.

And at the electronics companies, engineers were testing various electronic technologies for tracking vehicles, but had no experience in, and didn't know how to give more than rudimentary messages to the driver. For example, early systems used a bell tone or an arrow to signal a turn. Other early systems provided some spoken output such as "left" or "right."[2]

[2] One example of an early system is disclosed in the Wootton patent, which described a system with a 26-word vocabulary for speech – hardly sufficient for simple speech, must less discourse. Other prior art systems only produced single word outputs such as "left," "right," or "straight" (Zeevi). Other systems at the time gave only turn instructions such as "turn left" or "turn right" (CARIN, EVA). Finally, there were systems which provided static instructions

But none of these systems provided instructions or other messages in real-time according to a sophisticated set of linguistic rules.

During the early period of automobile navigation research, from 1986 to 1990, inventor James R. Davis ("Davis") was a graduate student at the MIT Media Laboratory ("Media Lab") in the Speech Research Group under the guidance of co-inventor Christopher M. Schmandt ("Schmandt"). At the time, Davis was working on a software program called "Direction Assistance" that could generate static directions of a route from the driver's origin (e.g., current position) to a destination. Exh. 2 at 1-2. Direction Assistance was a "static" direction giving program because, like a web-based program like Mapquest, the route was given to the driver in a single communication as a static list of instructions for the driver to write down or remember.

Davis completed his Direction Assistance program sometime before June of 1988, and it was such a hit, it was prominently displayed at the Computer Museum in Boston. To use the Direction Assistance program, a user would dial a telephone number that was interfaced to a computer at MIT running the Direction Assistance program. The user would then input both his or her current location and the desired destination using the telephone keypad. The computer planned a short, simple route from the user's location to the destination using a route-finding algorithm, and the route was then given to the user via spoken, step-by-step instructions.

B. <u>Davis and Schmandt Invent "The Back Seat Driver"</u>

Around June 1988, Davis and Schmandt realized that automobile drivers would prefer a direction-giving system that could provide sophisticated spoken driving instructions <u>*in real-time*</u>. The idea was to build a system which would allow the driver to get, and then to react to,

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(such as you would get from Mapquest), and attempted to read them while the driver was driving (NavTech).

individual driving directions -- rather than merely referring to the static instructions provided at the beginning of a trip. They believed that drivers would be more likely to use a navigation system that was relatively easy to use and that provided instructions like a person knowledgeable about the route -- like a "back seat driver." At the time, there was no such product in existence.

Davis and Schmandt brought something special to the table in doing this work -- unlike those in the GPS or map-making industries -- being in the heart of the MIT Media Lab, they uniquely understood newly-developed theories being published in the computer science literature relating to natural language processing and computational linguistics. (Davis had recently taken a course at Harvard in computational linguistics and discourse theory and conducted research at AT&T Bell Laboratories on the interrelationship between intonation and discourse.) Davis and Schmandt understood that the incorporation of sophisticated instructions of the type generated according to a "discourse model," would reduce the demands on the driver's attention while traversing a route.

A major technical obstacle they faced -- one that had never been addressed or published in the literature at the time -- related to how to provide real-time spoken instructions to the driver, e.g., "what to say" and "when to say it." Exh. 1 at 2:35-37, 44. Another technical obstacle related to how to integrate the sophisticated spoken directions with the positioning and location equipment that tracked the automobile's progress along the route.

C. The Back Seat Driver Invention Resulted in a Ph.D Thesis, Peer Reviewed Publications, a <u>Presentation at the First Major Industry Conference, and the '685 Patent</u>

As a result of their Back Seat Driver work, U.S. Patent Application No. 07/565,274 was filed on August 9, 1990, and issued on January 5, 1993, as U.S. Patent No. 5,177,685 ("the '685 patent"), with Davis and Schmandt listed as inventors. The '685 patent is titled "Automobile

Navigation System Using Real Time Spoken Driving Instructions." The ’685 patent issued with one independent claim and 57 dependent claims directed to an automobile navigation system which produces spoken instructions and other messages according to a "discourse model" to direct a driver of an automobile to a destination in real time, and various features and components of such a system. Exh. 1 at Abstract; 3:35-38.

The invention of the ’685 patent combined principles from computational linguistics, natural language processing, and discourse theory (including discourse generation), with known automobile navigation technology, to generate driving instructions modeled after those given by people. Exh. 1 at 2:34-35. In particular, the ’685 patent describes an automobile navigation system that knows "what to say (content) and when to say it (timing)." Exh. 1 at 2:36-37.

The key concept in the ’685 patent is the implementation of driving instructions according to a "discourse model." Exh. 1 at columns 13-23. A "discourse model" is a way to provide information needed by a driver in context to enable the driver to determine why an instruction or other message was provided and what the instruction or other message means. A discourse model also provides contextual information to enable the speaker or navigation system to know what to say and how to express it. A discourse "model allows the program (or programmer) to create and manipulate discourse segments." Exh. 1 at 23:16-17. Davis and Schmandt understood that a discourse model makes instructions more intelligible and provides a context for each instruction relative to other instructions, for example multiple utterances for a single maneuver. The incorporation of a discourse model into the navigation system facilitated provision of sophisticated instructions in a principled and reproducible way. Exh. 3 at ¶¶ 11-12.

At the time, the leading expert in the field of "discourse theory" for computer systems was Professor Barbara Grosz of Harvard University, who is now the Dean of Science at the

Radcliffe Institute from Advanced Study and Higgins Professor of Natural Sciences in the Division of Engineering and Applied Sciences at Harvard University. Dr. Grosz has agreed to testify on MIT's behalf in this matter, and in her expert report, she identifies Davis and Schmandt's Back Seat Driver as the *first* system to implement the theoretical constructs set forth in her foundational paper on natural language processing and discourse theory. Exh. 3 at ¶ 12. Indeed, Dr. Grosz opines that "James Davis' Ph.D thesis [from which the patent-in-suit springs] and the '685 patent are the first papers that describe in detail mechanisms for discourse-generating algorithms that produce intelligent spoken directions to direct a driver to a destination." Exh. 3 at ¶ 12. She believes that Davis' thesis was the *first* paper to describe how such a system could be built, programmed and replicated by others. Exh. 3 at ¶ 11.

Indeed, the Back Seat Driver and the invention of the '685 patent were recognized at the time as a technical tour de force by other experts who were in the industry, including Dr. Lynn Streeter, who had co-authored a seminal research paper on navigational direction-giving five years earlier. (Dr. Streeter has also agreed to testify on MIT's behalf in this case.) According to Dr. Streeter, five years passed between Dr. Streeter's report and the first "operational real-time navigation system in an automobile environment that provided real-time spoken instructions that were similar to those a human would give" implemented by Davis and Schmandt. Exh. 4 at ¶ 55.

Most interesting, perhaps, is that *Harman's* technical expert, Robert French, has testified in this case that as co-chair of the "first major technical conference … devoted exclusively to topics relating to vehicle navigation and route guidance," -- VNIS '89-- he was charged with selecting the "best papers" that he could find that would be of technical interest to conference attendees. Exh. 5 at 119:13-19; 121:8-23 (filed under seal). *Mr. French* recognized the work of Davis and Schmandt as "fresh" and "different" at the time and selected their paper for

presentation, because he thought that the Back Seat Driver took a "thorough approach" to using "longer and more detailed descriptions" of driving instructions as speech output from a navigation system. Exh. 5 at 93:19-23; 94:9-18; 210:3-6; 211:15-19 (filed under seal). Because of this freshness and difference from existing navigation systems, Mr. French selected the Back Seat Driver for presentation at the VNIS '89 conference. Exh. 6 at 3 n. 1; Exh. 5 at 114:1-5 (filed under seal).

D. <u>The Patented Invention Was Broadly Described</u>

Figure 1 of the '685 patent is below, and it schematically illustrates the primary components of the Back Seat Driver invention:

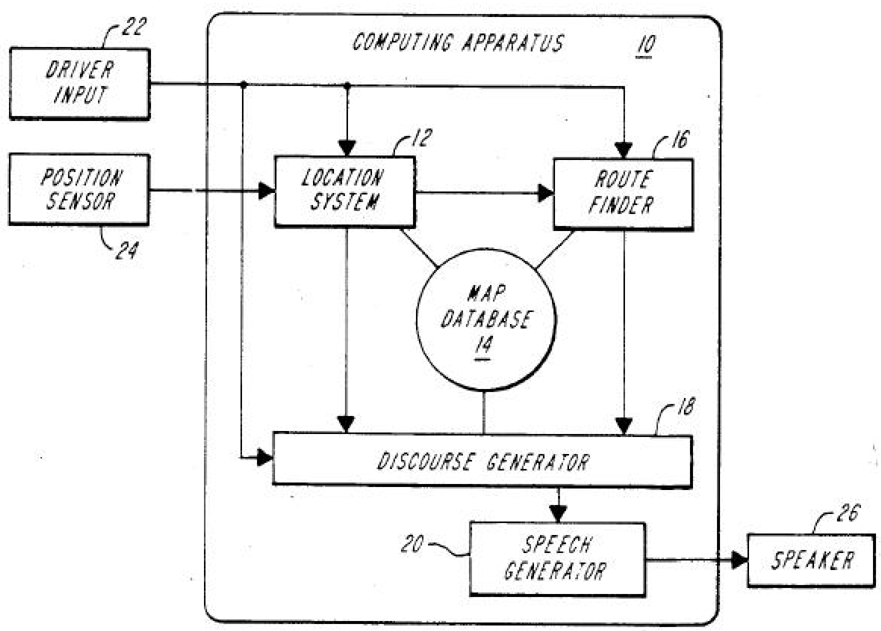

FIG. 1

The Back Seat Driver invention includes a driver input 22, a computing apparatus 10, a map database 14, a position sensor 24, a location system 12, a route-finder 16, a discourse generator 18, a speech generator 20, and a speaker 26.

The system illustrated in Figure 1 of the '685 patent broadly describes the organization of almost all modern automobile navigation systems. For example, Harman (through its subsidiary Harman-Becker Automotive Systems GmbH), has filed patent applications in the U.S. directed to aspects of Harman's navigation equipment. Many of these patent applications include diagrams similar to Figure 1 of the '685 patent above. For example, Figure 2 of U.S. Patent Application No. 10/528,526 (Publication No. 2006/0031009), assigned to Harman-Becker Automotive Systems GmbH, looks quite similar to the MIT invention:

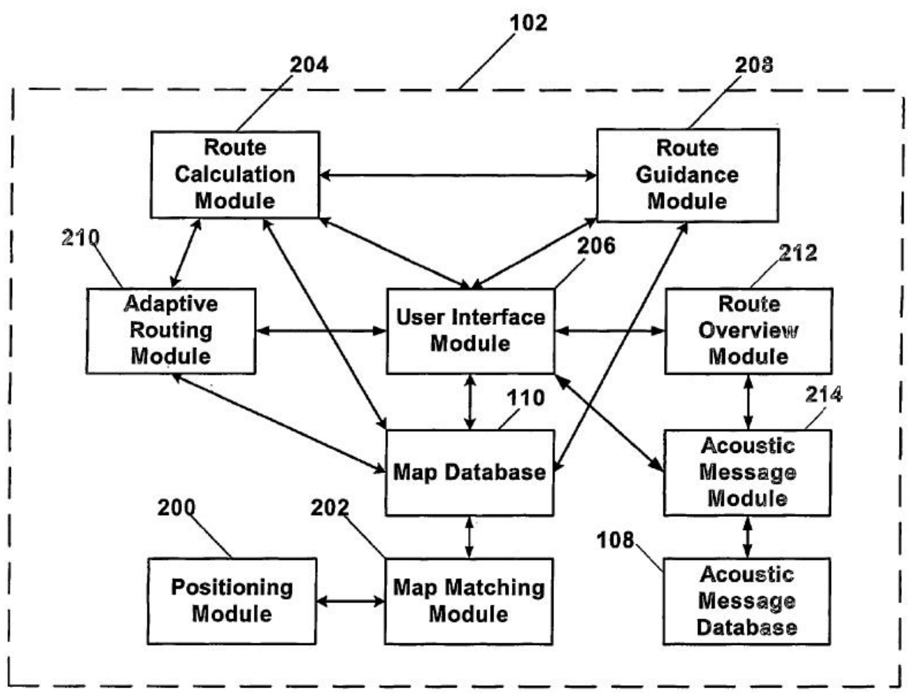

Figure 2

As can be seen from Harman's Figure 2 above, Harman's current navigation systems include a User Interface Module 206 (corresponding to the driver input 22 of MIT's Figure 1), Positioning Module 200 (corresponding to the position sensor 24 of MIT's Figure 1), a Map Matching Module 202 (corresponding to the MIT location system 12), a Map Database 110 (corresponding to the map database 14 of MIT's Figure 1), a Route Calculation Module 204 and

Adaptive Routing Module 210 (corresponding to the route-finder 16 of MIT's Figure 1), and a Route Guidance Module 208, Acoustic Message Module 214, and Acoustic Message Database 108 (corresponding to the discourse generator 18 and speech generator 20 of MIT's Figure 1). Loudspeakers 118 are used to generate audible sounds that are produced for the driver, such as driving directions. Exh. 7 at Fig. 1; ¶¶ [0030], [0040].

IV. IT IS A 'BEDROCK PRINCIPLE' OF PATENT LAW THAT 'THE CLAIMS OF A PATENT DEFINE THE INVENTION TO WHICH THE PATENTEE IS ENTITLED'

A. Claim Interpretation Is A Matter of Law For Determination By The Court

Claim construction is determined as a matter of law by the court. *Markman v. Westview Instruments, Inc.*, 517 U.S. 370, 391 (1996). "It is a 'bedrock principle' of patent law that 'the claims of a patent define the invention to which the patentee is entitled the right to exclude.'" *Phillips v. AWH Corp.*, 415 F.3d 1303, 1312 (2005) (quoting *Innova/Pure Water, Inc. v. Safari Water Filtration Sys., Inc.*, 381 F.3d 1111, 1115 (Fed. Cir. 2004)).

Understanding the "invention" is essential to an accurate delineation of the patentee's rights:

> Ultimately, the interpretation to be given a term can only be determined and confirmed with a full understanding of what the inventors actually invented and intended to envelop with the claim. The construction that stays true to the claim language and most naturally aligns with the patent's description of the invention will be, in the end, the correct construction.

Renishaw PLC v. Marposs Societa' Per Azioni, 158 F.3d 1243, 1250 (Fed. Cir. 1998) (citation omitted); *accord Phillips*, 415 F.3d at 1316. The claims must be read in the context of the problems solved, and with a common sense approach to the objectives of the invention. *See, e.g., Pall Corp. v. Micron Separations, Inc.*, 66 F.3d 1211, 1217 (Fed. Cir. 1995) ("the word

'about' does not have a universal meaning in patent claims, and…the meaning depends on the technological facts of the particular case…[and i]ts range must be interpreted in its technologic and stylistic context.").

It is a fundamental tenet of patent law that in construing a claim the Court must start with the language in the claim itself. *Phillips,* 415 F.3d at 1312; *see also Bell Commc'ns. Research, Inc. v. Vitalink Commc'ns. Corp.*, 55 F.3d 615, 619 (Fed. Cir. 1995) ("First, and most importantly, the language of the claim defines the scope of protected invention."). In construing claims, there is a "'heavy presumption' that a claim term carries its ordinary and customary meaning." *CCS Fitness, Inc. v. Brunswick Corp.*, 288 F.3d 1359, 1366 (Fed. Cir. 2002) (quoting *Johnson Worldwide Access, Inc. v. Zebco Corp.*, 175 F.3d 985, 989 (Fed. Cir. 1999)). *See Vitronics Corp. v. Conceptronic, Inc.*, 90 F.3d 1576, 1582 (Fed. Cir. 1996). "'[R]esort must be had in the first instance to the words of the claim,' words to which we ascribe their ordinary meaning unless it appears the inventor used them otherwise." *Bell*, 55 F.3d at 620 (quoting *Envirotech Corp. v. Al George, Inc.*, 730 F.2d 753, 759 (Fed. Cir. 1984)).

The most important evidence relating to the meaning of claim terms is the intrinsic evidence, that is, the claims themselves, the specification, and the file history. Extrinsic evidence has a limited role in claim construction: "[i]n most situations, an analysis of the intrinsic evidence alone will resolve any ambiguity in a disputed claim term. In such circumstances, it is improper to rely on extrinsic evidence." *Vitronics Corp.*, 90 F.3d at 1583. "Extrinsic evidence is to be used for the court's understanding of the patent, not for the purpose of varying or contradicting the terms of the claims." *Markman v. Westview Instruments, Inc.*, 52 F.3d 967, 981 (Fed. Cir. 1995) (*en banc*) *aff'd*, 517 U.S. 370 (1996).

V. CONSTRUCTION OF THE ASSERTED PATENT CLAIMS

A. Claim 1

Claim 1 of the patent is the one independent claim in the case. It reads:

> An automobile navigation system which produces spoken instructions to direct a driver of an automobile to a destination in real time comprising:
>
> computing apparatus for running and coordinating system processes,
>
> driver input means <u>functionally connected</u> to said computing apparatus for <u>entering data</u> into said computing apparatus, said data including a desired destination,
>
> a map database functionally connected to said computing apparatus <u>which distinguishes between physical and legal connectivity</u>,
>
> position sensing apparatus installed in the automobile and functionally connected to said computing apparatus for providing said computing apparatus data for determining the automobile's current position,
>
> a location system functionally connected to said computing apparatus for accepting data from said position sensing apparatus, for <u>consulting said map database</u>, and for determining the automobile's current position relative to the map database,
>
> a route-finder functionally connected to said computing apparatus, for accepting the desired destination from said driver input means and the current position from said location system, for consulting said map database, and for computing a route to the destination,
>
> <u>a discourse generator</u> functionally connected to said computing apparatus for accepting the current position from said location system and the route from said route finder, for consulting said map database, and for composing discourse including instructions and other messages for directing the driver to the destination from the current position,
>
> a speech generator functionally connected to said discourse generator for generating speech from said discourse provided by said discourse generator, and
>
> voice apparatus functionally connected to said speech generator for communicating said speech provided by said speech generator to said driver.

1. "<u>a discourse generator</u> functionally connected to said computing apparatus for accepting the current position from said location system and the route from said route finder, for consulting said map database, and for composing discourse including instructions and other messages for directing the driver to the destination from the current position,"

Terms to be Construed	MIT's Construction	Harman's Construction
"discourse generator"	A module, in software or hardware, which composes driving instructions and other messages according to a *discourse model*, for delivery at the appropriate time and place, and based on the current position of a vehicle and its planned route. **discourse model**: a way to provide information needed by a hearer conversation participant in context to enable the hearer conversation participant to determine why an utterance was provided and what the utterance means. A discourse model provides contextual information and the discourse state to enable a speaker conversation participant to know what to say and how to express it.	Discourse means "instructions and other messages," and a "discourse generator" generates discourse, i.e., instructions and other messages.

The discourse generator element is the heart of the invention, because it is what makes the invention special and unique -- the inventors *<u>invented and built</u>* the first navigation system to provide spoken instructions and other messages "as a passenger in the car familiar with the route would." Exh. 1 at 13:25-26. The key problem solved by the inventors and described in the patent is the proper "content and timing of the instructions and other messages" or "what to say" and "when to say it." Exh. 1 at 2:33-37; 13:26-28. The inventors solved this problem by being the first ever to use a "discourse model" that provided instructions and other messages based on

upcoming actions required by the driver. To do their work, Davis and Schmandt studied the content and timing of driving instructions given by a passenger knowledgeable about a route, and then conceived and built a system that could replicate those instructions. Exh. 1 at 13:24-29; Exh. 8 at 22-39.

Because the term "discourse generator" is not itself a standard term or a special term in the art where a dictionary can help, the court must understand the invention and what the inventors intended when they used the term "discourse generator" in the patent. The inventors made clear in the patent what they meant:

> Based on the current position of the automobile and the route. the discourse generator **18** composes driving instructions and other messages according to a discourse model in real time as they are needed. The in-

Exh. 1 at 3:35-38.

> The discourse model preferred for the Back Seat Driver is a partial implementation of the discourse theory described by B. J. Grosz and C. L. Sidner ("Attention, intentions, and the structure of discourse" in *Computational Linguistics,* 12(3):175–204, 1986) and the theory of intonational meaning described by J. Hirschberg and J. Pierrehumbert ("The intonational structuring of discourse" in *Proceedings of the Association for Computational Linguistics,* 136–144, July 1986). Both of these articles are herein incorporated by reference. This model allows the program (or programmer) to create and manipulate discourse segments. The program specifies the contents of the discourse segment (both the syntactic form and the list of objects referenced) and the implementation of the model does the following: generates prosodic features to convey discourse structure; inserts discourse segment into intentional structure; and maintains attentional structure—adding new objects when mentioned and removing old objects when replaced. In addition it includes some useful low-level tools for natural language generation: search of attentional structure for occurence of co-referential objects; conjugation of verbs; generation of contracted forms; and, combination of sentences as "justification" sentences (e.g. "get in the right lane because you are going to take a right.") and sequential sentences ("Go three blocks, then turn left"). In order to use the discourse package the programmer must explicitly declare all semantic types used by the program, so in this case there are declarations for all objects which pertain to driving, such as street names, bridges, rotaries, stop lights and so on.

Exh. 1 at 23:6-32. This is precisely the definition MIT seeks here -- nothing broader, and nothing narrower.

Harman, on the other hand, tries to trivialize the importance of the discourse generator by arguing that *any* driving instruction is "discourse." The fact is, there is a science to providing good driving instructions that are intelligent and easy to follow to the destination. The patent dedicates approximately *ten columns* of text to explaining the application of these concepts in the

context of an automobile navigation system. Exh. 1 at columns 13-23. Discourse is more than just words or instructions -- it is a dialogue between the user and the speaker, where one sentence has meaning in the context of earlier sentences.

a. A "Discourse Generator" Does More Than Simply Produce Words

A "discourse generator" includes the software algorithms that determine what to say and when to say it based on the driver's position and the route. A "discourse model" provides a scheme for generating instructions and messages *in context*, to make them understandable to the driver. The content and timing of the instructions are governed by the "discourse model." Exh. 1 at Abstract; 3:35-38. As MIT's expert Barbara J. Grosz, Ph.D. stated in her expert report, "the three constituents of discourse structure – attentional state, intentional structure, and linguistic structure – supply information to participants in the conversation to enable the participants to generate utterances appropriate in context and understand what was said and why it was said." Exh. 9 at ¶ 24.[3]

Harman knows its products generate discourse, however it is defined, and therefore Harman argues here for the broadest possible construction to set up an invalidity defense. It is for this reason that Harman's expert, Dr. Litman, repeatedly refers to "the broader understanding of the term 'discourse,'" even though the patent specification does not refer to discourse in that "broader" context at all. Dr. Litman suggests that "the term 'discourse' can be defined as simply text or speech consisting of more than one sentence or utterance, respectively" and that "discourse" should even be defined using ordinary English dictionaries, even though the claim

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[3] Although the Expert Report of Barbara J. Grosz, Ph.D. is marked "Highly Confidential" in its entirety, the excerpts contained in Exhibit 9 do not contain the confidential information of either party.

refers to a "discourse generator" and the inventors described "discourse generation" with great detail in the patent. See Exh. 10 at 5-6.

Interestingly, Dr. Litman's academic writings on the subject of discourse are quite contrary to her opinion here. Dr. Litman writes that:

> *A discourse consists not simply of a linear sequence of utterances, but of meaningful semantic or pragmatic relations among utterances*.

Exh. 11 at 161. Dr. Litman also states that "[c]ue words (e.g., *now*) are words that are sometimes used to explicitly signal the structure of a discourse." Exh. 11 at 179. According to Dr. Litman, "[e]ach utterance of a discourse contributes to the communicative import of preceding utterances, or constitutes the onset of a new unit of meaning or action that subsequent utterances may add to." Exh. 12 at 1.

Thus, even Dr. Litman confirms that the content and timing of the spoken output of a navigation system are what makes spoken instructions and other messages become discourse according to a discourse model.

The term "discourse generator" in the claim should be given exactly the meaning the inventors described in the patent:

> the *discourse generator 18* composes driving instructions and other messages *according to a discourse model* in real time as they are needed.

Exh. 1 at 3:35-38.

2. "computing apparatus for running and coordinating system processes,"

MIT and Harman agree that the terms of this element should be given their "plain and ordinary" meaning to one of skill in the art. However, the parties seem to disagree regarding what the term "computing apparatus" means.

MIT contends that this term includes a computer-processor-based system that performs computer operations to process data. As MIT understands Harman's position, Harman would limit this element to computers and software for running only the computers that existed as of the filing date of the application for the '685 patent (i.e., August 9, 1990), but no later.

There is no basis in the law for Harman to graft such a limitation on the claim. Under Harman's construction, a patent would never cover new technology that developed after the invention, even if it included the invention itself. Of course, it is well-settled that unless specifically time-limited, a claim is _not_ limited only to embodiments existing at the time of the invention. *SuperGuide Corp. v. DirecTV Enters., Inc.* 358 F.3d 870, 878 (Fed. Cir. 2004) ("The claim language does not limit the disputed phrases to any particular type of technology or specify a particular type of signal format."). The *SuperGuide* court also stated that "[t]he law 'does not require that an applicant describe in his specification _*every conceivable and possible future embodiment of his invention*_.'" *Id.* at 880 (quoting *SRI Int'l v. Matsushita Elec. Corp. of Am.*, 775 F.2d 1107, 1121 (Fed. Cir. 1985)).

3. "*driver input means* functionally connected to said computing apparatus *for entering data into said computing apparatus*, said data including a desired destination,"

MIT and Harman agree that this claim element is written in the "means-plus-function" format governed by 35 U.S.C. § 112, ¶ 6. That statute provides that:

> An element in a claim for a combination may be expressed as a means or step for performing a specified function without the recital of structure, material, or acts in support thereof, and such claim shall be construed to cover the corresponding structure, material, or acts described in the specification and equivalents thereof.

The parties further agree that the MIT specification discloses several ways to perform the claimed function, including a computer keyboard, a telephone keypad, or speech input. Exh. 1 at 20:67-21:13; 23:62-24:60.

Where MIT and Harman disagree is that Harman wants the claim to be narrowly construed to cover only the situation where the destination is actually typed into the system, as opposed to where letters are selected by the user one at a time until the destination is determined or where the user selects an address from a list. Harman proposes a contrived function for the "driver input means" which excludes systems that allow the driver to ***select*** a destination. The dispute boils down to whether ***selecting*** a destination from a list, is in fact a form of ***entering*** data into the computer system. Harman's proposal confuses two facts: simply because a driver might "select" a letter from a keypad, that doesn't mean that once the driver selects the correct key to type, *data* is not entered into the computer. In fact, data which tells the system what the correct destination is, is entered into the system once the destination is selected.

a. "function" performed by "driver input means"

Terms to be Construed	MIT's Construction	Harman's Construction
"function" of "driver input means"	The ***driver input means*** is a computer keyboard, a telephone keypad, or speech input; the ***function*** is entering data.	***Function:*** "entering data into said computing apparatus, said data including a desired destination." Entering data does not include selecting data stored in the computing apparatus.

The purpose of this element -- the "driver input means" -- is to allow the driver to tell the system where he or she wants to go.

A means-plus-function claim should be construed to cover the product described in the patent, and its equivalents:

> In construing a means-plus-function limitation, a court must identify both the claimed function and the corresponding structure in the written description for performing that function…Under § 112, ¶ 6, a court may not import functional limitations that are not recited in the claim, or structural limitations from the written description that are unnecessary to perform the claimed function.

Wenger Mfg., Inc. v. Coating Mach. Sys., Inc., 239 F.3d 1225, 1233 (Fed. Cir. 2001) (citation omitted). "In construing a means-plus-function claim limitation, the recited function within the limitation must first be identified… 'Then the written description must be examined to determine the structure that corresponds to and performs the function.'" *Gemstar-TV Guide v. Int'l Trade Comm'n*, 383 F.3d 1352, 1361 (Fed. Cir. 2004) (quoting *ACTV Inc. v. Walt Disney Co.*, 346 F.3d 1082, 1087 (Fed. Cir. 2003)).

Here, according to the patent, the "function" of the "driver input means" is "entering data." *See e.g.*, Exh. 1, Abstract ("Driver input means allows the driver to *enter* information such as a desired destination"); 3:28-30 ("Driver input means 22 allows the driver to *input* to the computing apparatus 10 information such as a desired destination"); 7:8-10 ("The Back Seat Driver should allow the driver to *select* famous destinations by name in addition to address by including this information in a database"). A driver using the invention "selects" a destination from the map database by typing the information on the keyboard or keypad. If the system recognizes the destination, processing begins. If the driver has selected an unrecognizable destination, the user is prompted to make another selection. Exh. 1 at 24:5-44; Exh. 8 at 102-103; Exh. 13 at 2-3.

The phrase "entering data" should be given the meaning made clear in the patent, namely, "communicat[ion]" with the [B]ack [S]eat [D]river system to provide destination information.

Exh. 1 at 23:64-65. As the patent describes, "entering" data is the same as "inputting" data: "Driver input means 22 *allows the driver to input to the computing apparatus* 10 information such as a desired destination." Exh. 1 at Abstract; 3:28-30. In addition to the patent, Davis' thesis, which is incorporated by reference into the '685 patent, describes features of the driver interface to the computing apparatus. Exh. 8 at 102-103; *see also* Exh. 13 at 2-3 (describing at least four ways to enter or input data, a) yes/no questions, b) *selection from a list*, c) number entry, and d) name entry) (emphasis added).

As described in the patent, the inventors showed how drivers could "select" a destination from a list of destinations stored in the computing apparatus when the driver entered a destination that existed in multiple locations. Exh. 1 at 24:19-44. According to the patent, the driver's destination was "input," "entered," or "selected" by the driver.

> Abstract:
> *Driver input means* allows the driver to *enter* information such as a desired destination.
>
> Col. 3, ll. 28-30:
> *Driver input means* 22 allows the driver to *input* to the computing apparatus 10 information such as a desired destination.
>
> Col. 7, ll. 8-27:
> *The Back Seat Driver should allow the driver to select famous destinations by name in addition to address* by including this information in a database, and this database should be integrated with the services database, discussed below. The Back Seat Driver should also support names of buildings and office plazas made up by developers without reference to the street names.
>
> Service locations are preferably stored in a services database. This database lists services such as gas stations, automatic teller machines and stores. For each service is recorded the name of the establishment, the address, phone number, and hours of operation. *This allows the Back Seat Driver to select the closest provider of a service known to be open.* The database can also be used as a source of landmarks when giving directions.
>
> The map database preferably contains information on the division of the city into neighborhoods. *This is useful for selecting an address.*

Exh. 1 (emphasis added).

Regardless of the choice of word -- entering or selecting -- the result is the same -- the computing apparatus can plan a route to the destination and begin guiding the driver to the destination. The proper function of the "driver input means" is entering data.

b. "functionally connected"

Terms to be Construed	MIT's Construction	Harman's Construction
"functionally connected"	Connected in a way that facilitates transmission of information, where said transmission of information may be bi-directional between system components; this need not be a physical connection (Agreed-upon meaning for all claim elements)	Connected in a way that facilitates transmission of information, wherein said transmission of information is not bi-directional between the driver input means and the computing apparatus but can be bi-directional for other system components.

Although the parties agree that in **seven** instances in this claim, "functionally connected" means:

> connected in a way that facilitates transmission of information, where said transmission of information may be bi-directional between system components; this need not be a physical connection

Harman contends that in one instance -- the first instance in the claim -- the term has a special, different, unique meaning.

It seems that in this one instance, Harman seeks to narrow this claim term to cover data transfer in only one direction, as opposed to bi-directional data transfer. Of course, there is nothing in the choice of words MIT used in the claim to limit the data flow to one direction, as opposed to bi-directionally. The claim simply requires that the components be connected

functionally to transmit data. Indeed, the same term is used throughout the claim -- and Harman concedes that sometimes, it refers to bi-directional data transfer, and sometimes to uni-directional data transfer.

MIT's proposed construction for "functionally connected" is consistent with the use of "functionally connected" throughout the claim and in the description of the invention in the specification. Harman's proposed construction, on the other hand, would result in one construction for the functional connection between the "driver input means" and the "computing apparatus," and a second different construction for the same words, when used in connection with the other components of the automobile navigation system. Harman provides no basis for these differing constructions and appears to propose the different constructions merely to support its non-infringement argument.

The phrase "functionally connected" appears throughout claim 1 of the '685 patent to describe communication of data between the components of the claimed invention:

a) driver input means *functionally connected* to said computing apparatus for entering data into said computing apparatus, said data including a desired destination,

b) a map database *functionally connected* to said computing apparatus;

c) position sensing apparatus installed in the automobile and *functionally connected* to said computing apparatus for providing said computing apparatus data for determining the automobile's current position,

d) a location system *functionally connected* to said computing apparatus for accepting data from said position sensing apparatus, for consulting said map database, and for determining the automobile's current position relative to the map database,

e) a route-finder *functionally connected* to said computing apparatus, for accepting the desired destination from said driver input means and the current position from said location system, for consulting said map database, and for computing a route to the destination,

f) a discourse generator *functionally connected* to said computing apparatus for accepting the current position from said location system and the route from said route finder, for consulting said map database, and for composing discourse including instructions and other messages for directing the driver to the destination from the current position,

g) a speech generator *functionally connected* to said discourse generator for generating speech from said discourse provided by said discourse generator, and

h) voice apparatus *functionally connected* to said speech generator for communicating said speech provided by said speech generator to said driver.

The patent makes clear that each separate component is functionally connected to another component: the "driver input means," "map database," "position sensing apparatus," "location system," "route-finder" and "discourse generator" are all "functionally connected" to the "computing apparatus" to allow the exchange of data between these components; the "speech generator" is functionally connected to the "discourse generator;" and the "voice apparatus" is functionally connected to the "speech generator." The parties agree that the functional connection between elements of the claimed system need not be a direct connection or a physical connection.

Harman's proposed construction would result in the term "functionally connected" having two different meanings within the claim, contrary to well-established canons of claim interpretation. *Pitney Bowes, Inc. v. Hewlett-Packard, Inc.*, 182 F.3d 1298, 1310 (Fed. Cir. 1999) ("Certainly, 'the same word appearing in the same claim should be interpreted consistently.'") (quoting *Digital Biometrics, Inc. v. Identix, Inc.*, 149 F.3d 1335, 1345 (Fed. Cir. 1998)). Harman intends to argue that its navigation system products do not infringe because the driver interface of Harman's systems permit two-way communication between the driver and the navigation system.

The "functional connection" between the driver input means and the computing apparatus should be construed to have the same meaning as the "functional connection" between other components of the claim, namely a connection that facilitates bi-directional flow of data and that need not be a direct or physical connection.

4. "*a map database* functionally connected to said computing apparatus *which distinguishes between physical and legal connectivity*,"

MIT and Harman agree that the court does not need to construe "map database," "functionally connected," or "physical connectivity" and "legal connectivity." The parties agree that those terms mean:

map database: Harman does not dispute that its products use a map database.

functionally connected: connected in a way that facilitates transmission of information, where said transmission of information may be bi-directional between system components; this need not be a physical connection.

Physical connectivity: how pieces of pavement connect or whether two segments touch. Exh. 1 at 2:13-14; 4:64-65.

Legal connectivity: whether one can legally drive onto a physically connected piece of pavement or whether it is legal to travel from one segment to another. Exh. 1 at 2:14-16; 4:66-67.

So, "physical connectivity" is whether two pieces of pavement are physically connected; and "legal" connectivity is whether a car can legally drive from one pavement to the other (e.g., is there a "no left turn" sign at the intersection.).

MIT and Harman differ substantially regarding the construction of the phrase "*a map database…which distinguishes between physical and legal connectivity*."

Terms to be Construed	**MIT's Construction**	**Harman's Construction**
"which distinguishes between physical and legal connectivity"	Contains information on both physical and legal connectivity and arranged so that the computing apparatus can gain access to this information.	Separate but equal databases for representing each of physical and legal connectivity, thereby causing the route-finder to consider only legal paths; this excludes a map database in which legal connectivity is represented as a link attribute.

MIT believes that the phrase "map database…which distinguishes between physical and legal connectivity" has a plain and ordinary meaning. The term refers to a map database which contains information on both physical and legal connectivity and arranged so that the computing apparatus can gain access to this information. In the patent -- indeed a key teaching of the patent that facilitated efficient route-finding and discourse generation -- is the concept of including information about <u>*both*</u> physical and legal connectivity. The distinction between physical and legal connectivity in the map database is a solution to a problem recognized by Davis and Schmandt, namely that finding a route differs from providing spoken output according to a discourse model for guiding the driver along the route. Exh. 1 4:66-5:5; Exh. 3 at ¶¶ 6-7.

Under Harman's construction, even the preferred embodiment of the '685 patent would not be covered by the claim. The database of the preferred embodiment included a single, integrated representation of physical and legal connectivity: "the map database 14 includes, as its basis, *a file 28 of segments and nodes*." Exh. 1 at FIG. 3; 8:6-7 (emphasis added). As the Federal Circuit made clear in *Amgen, Inc. v. Hoechst Marion Roussel, Inc.*:

> A claim interpretation that reads out [of a claim] a preferred embodiment 'is rarely, if ever, correct and would require highly persuasive evidentiary support.'…We have done so only one time — in an instance where the patent applicant limited the full scope of the claim language to omit the preferred (and only disclosed) embodiment in order to overcome an examiner's rejection.

314 F.3d 1313, 1349 (Fed. Cir. 2003) (internal citation omitted).

As the '685 patent explains, because automobile navigation systems were just beginning to be developed at the time, map databases available to Davis and Schmandt when they made their invention lacked *legal* connectivity information:

> [t]he map database for the Back Seat Driver in the working prototypes originated as a DIME (Dual Independent Map Encoding) file, a map format invented by the U.S. Census Bureau for the 1980 census. Implementing the Back Seat Driver required *extending* the DIME map format in a number of ways to make it useful for route finding and route describing…The most important problem with the DIME format is that it indicates *only if two segments are physically connected* (that is, if they touch), *but not whether they are legally connected* (i.e., whether it is legal to drive from one to the other)." Exh. 1 at 4:13-19, 63-67.[4]

The inventors understood that for a route finder to operate at all, the map database must include a representation of legal connectivity. If legal connectivity information was not included, the route-finder would potentially plan routes that were physically connected but illegal to travel.

To make the invention work, Davis added legal connectivity to the map database file by adding a "legal connection list" to the endpoints (nodes) of the map segments, which allowed the route-finder to plan legal routes. Exh. 1 at 5:8-11. In to the '685 patent, the purpose of including both physical and legal connectivity in the map database is explained: "Legal connectivity is essential for route-finding, and physical connectivity for describing the route." Exh. 1 at 2:16-18. Moreover, "legal connectivity is crucial for route finding. However, legal connectivity does

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[4] The data arrangement in the DIME file was a two-dimensional planar graph such that if two segments intersected on the planar graph, then all maneuvers were presumed to be legal. Exh. 1 at 5:15-25. For example, underpasses and overpasses were represented as intersections in the DIME file (without off-ramps and on-ramps). *Id.* at 5:16-25. Based on the information in the DIME file, then-existing route-finding algorithms would return routes that required a turn directly from an underpass onto an overpass, even though such a maneuver would require the automobile to "jump straight up" from the underpass onto the overpass. *Id.* at 5:22-25.

not replace physical connectivity; route description requires information about physical connections as well." Exh. 1 at 4:67-5:2.

Incorporating the concept of legal connectivity into a map database prevents the route-finding algorithm from *returning or producing* an illegal route to the driver, but the route-finder is not *required* to consider only legal routes. This key insight was based on the inventors' understanding that humans think about routes and instructions differently than computers do.

a. Dictionaries Provide an Ordinary Meaning of the Claim Language "Which Distinguishes Between Physical and Legal Connectivity" That Is Consistent With Use in the Patent

"A map database….which distinguishes between physical and legal connectivity" is not a special term of art which requires resort to special technical dictionaries. Rather, standard dictionaries can be used to ascertain the meaning of the words as understood within the context of the patent. The word "which" refers to the "map database," and "physical and legal connectivity" are defined in the specification as two separate attributes -- legal and physical connectivity. To the extent that the claim requires that the database "distinguish" between the two, the dictionary defines "distinguish" to mean "to perceive a difference in," "to separate into kinds," "to mark as separate or different," or to "take special notice of." Exh. 14 at 337. "Distinguish" similarly means "to make noticeable or different." Exh. 18 at 411.

The dictionary definition of "distinguish" comports with the definition set forth in the patent -- the original DIME map database that the inventors used did not provide separate physical and legal connectivity, because only physical connectivity was required. The inventors added additional, *different* connectivity information to the physical connectivity data in the database to reflect the real-world road network.

Harman argues that the term should mean:

> "Separate but equal databases for representing each of physical and legal connectivity, thereby causing the route-finder to consider only legal paths; this excludes a map database in which legal connectivity is represented as a link attribute."

That is, Harman argues that the claim requires that an infringing map database include two *separate* databases – one for physical connectivity and one for legal connectivity. Harman argues that these databases must be "separate but equal," without defining what those terms mean. Harman further requires the database be organized "such that the route-finder considers only legal paths."

Harman bases its special definition on a few "sound bites" taken out of the specification and file history. However, to support such a narrow construction, Harman needs to show that the inventors *clearly, deliberately,* and *precisely* intended to create their own definition, or that the file history evinces a "*clear*," "*unambiguous*," or "*unmistakable*" disclaimer or surrender of claimed subject matter. *Omega Eng'g, Inc. v. Raytek Corp.*, 334 F.3d 1314, 1324-1326; *IMS Tech., Inc. v. Haas Automation, Inc.*, 206 F.3d 1422, 1439 (Fed. Cir. 2000); *Renishaw PLC v. Marposs Societa' Per Azioni*, 158 F.3d 1243, 1248 (Fed. Cir. 1998).

Harman is able to do neither.

In fact, the patent states that the incorporation of physical and legal connectivity information into the database "*allows*" the route-finder to consider only legal paths, but does not *require* only legal paths to be considered. Again, Harman's narrow construction must be meant to avoid infringement, because Harman asserts, without identifying where in its technical documents, that its route-finder considers illegal paths, but then rejects them and therefore does not consider ***only*** legal paths. Exh. 16 at 14-15 (filed under seal). Of course, the exact method Harman uses to determine the route is of no import to the invention.

To push for its special narrow definition, Harman cites to one sentence in the patent's prosecution file history. Harman is trying to take this one statement out of context.

In following proper United States Patent and Trademark Office procedure, MIT filed an Information Disclosure Statement ("IDS") identifying prior art references that the inventors thought the Patent Office Examiner would deem material to patentability. *See* 37 C.F.R. § 1.56; Exh. 17 at MIT00336. The IDS was received by the Patent Office during the prosecution of the patent -- on September 4, 1990 and included a list of references and a description of the state of the art. Included was Davis' Ph.D. thesis for the Back Seat Driver. The Back Seat Driver described in Davis' Ph.D. thesis was, to the inventors' knowledge, the first working navigation system that provided instructions and other messages according to a discourse model. *See* Exh. 1 at cover page; Exh. 17 at MIT00326.

The IDS, portions of which were based on portions of Davis' thesis, describes related work in the field of navigation systems. Exh. 17 at MIT00337; Exh. 8 at 55-58, 98-109. The IDS was submitted to the Patent Office to put the Back Seat Driver in context, because it used a number of components that were otherwise available in the field. In this regard, in explaining their invention -- the first complex navigation system for generating instructions according to a discourse model -- the inventors noted that there were existing map databases which included legal topology information. Exh. 8 at 56; Exh. 17 at MIT00343-344.

Harman now cites to an isolated snippet of the IDS where MIT discussed one such database. However, in making its argument, Harman omits two critical contextual clues that illuminate the proper interpretation of this claim element. The passage Harman relies upon is presented in context below, with the critical contextual elements highlighted:

> These maps *have some questionable design decisions on the representation of legal restrictions*. The ETAK map has no legal topology at all. It is not intended

> for route finding. The EVA map apparently encodes restrictions on turning by signs, rather than directly in the network. The Calgary map represents legal topology (one ways, banned turns) as a link attribute instead of in the network topology, with the assumption that legal topology will be equivalent to the physical topology unless specially indicated.
>
> The Back Seat Driver appears to be unique in maintaining separate but equal representations for physical and legal topology. *These two topologies should be <u>integrated</u> because legal topology is needed for route-finding, and physical topology for route description.*

Exh. 17 at MIT00344; *see also* Exh. 8 at 57-58.

"The purpose of consulting the prosecution history in construing a claim is to 'exclude any interpretation that was disclaimed during prosecution.'" *Phillips*, 415 F.3d at 1317 (internal citations omitted). The patent claim, however, should not be limited by statements made in the file history where those statements "do not indicate a [clear and unambiguous] disavowal or disclaimer of claim scope,…but merely provide an example to illustrate differences between the invention and the prior art." *Gemstar-TV Guide Int'l, Inc. v. Int'l Trade Comm.*, 383 F.3d 1352, 1375 (Fed. Cir. 2004); *accord Omega Eng'g, Inc. v. Raytek Corp.*, 334 F.3d 1314, 1324-1326 (Fed. Cir. 2003); *IMS Tech., Inc. v. Haas Automation, Inc.*, 206 F.3d 1422, 1439 (Fed. Cir. 2000). Here, the specification and the claim augur for a plain and ordinary construction of this element with a common sense view of what the inventors invented. The prosecution history provides no additional insight into the meaning of "which distinguishes between physical and legal connectivity." The inventors' statements during prosecution do not evince a clear, unmistakable and unambiguous disavowal of the scope of the map database. *Omega Eng'g*, 334 F.3d at 1324-1326.

The IDS does not question the content or existence of legal connectivity in prior databases, nor how the map data was stored by the navigation system. The patent describes an alternative *design* decision that facilitated sufficiently fast processing by the computing

apparatus to enable the navigation system to reside in the automobile, namely, representing legal connectivity as the legal connection list in the DIME file.

Therefore, the claim should be construed to cover map databases that include information on both physical and legal connectivity and should include map databases that differentiate physical and legal connectivity (e.g., by a legal connection list or a "no turns" list).

5. "a location system connected to said computing apparatus for accepting data from said position sensing apparatus, *for consulting said map database*, and for determining the automobile's current position relative to the map database,"

MIT and Harman disagree over the proper construction of "for consulting said map database."

Terms to be Construed	MIT's Construction	Harman's Construction
"consulting said map database"	referring to or relying on map data from the map database; this does not require a direct connection or query of the map database	for the purpose of seeking or requesting information from said map database; this would require a direct connection or communication to the map database, such as by querying the map database

For the location system to "consult" the map database means that it "<u>refers to or relies on</u> information from the map database." Harman, however, seeks a special definition for this element by inserting the word "directly" in front of "consulting," so that the location system must <u>directly</u> access the entire map database, rather than just the data that is necessary for its use.

As described in the patent, the map database of the Back Seat Driver contains map data used by the "location system" (e.g., for map matching), the "route-finder" (e.g., for route-finding), and the "discourse generator" (e.g., for describing the route). Each of these elements uses data from the map database. Harman's proposed construction for "consulting said map

database" requires a direct, physical connection for querying the database, and would undermine the meaning of "functionally connected."

Nothing in the language of the patent specification or the claim suggests that any of these elements must *directly* query the map database. In fact, the location system queries the computing apparatus for map data; the location system does not directly query the map:

> . . . the map database used by the location system is completely distinct from the map database used by the route finder and discourse generator.

Exh. 1 at 13:5-8. The patent's abstract is in accord:

> "The vehicle location system accepts input from a position sensor which measures automobile movement (magnitude and direction) continuously, and *using this data in conjunction with the map database,* determines the position of the automobile."

Id. at Abstract. The plain and ordinary meaning of the term "consult" does not require a direct request or query of the database because map data is transmitted throughout the navigation system by the computing apparatus. The patent makes clear that data from the map database is available to the components of the claimed invention via the computing apparatus. Exh. 1 at Figs. 1 and 3. The patent specification allows for map data to be communicated to components of the navigation system indirectly.

The claim term "consulting" with reference to the map database is not some special term of art which requires resort to technical dictionaries. Rather, standard dictionaries can be used to ascertain the claim meaning.

According to the dictionary, "consult" means "refer to," as in a dictionary or other reference (e.g., map data). Exh. 14 at 248. "Consult" also means "[t]o seek advice or information of…[t]o refer to…[t]o take into account; consider." Exh. 15 at 307. WordNet 2.1, Princeton University, defines "consult" as "seek information from." Exh. 18.

Harman's special definition for the word "consulting" seeks to artificially narrow the scope of the claim to "directly consulting." But, the inventors' own prototype did not have a direct connection between the map database and the location system. In fact, the location system received map data indirectly, via a CDROM reader. "A claim interpretation that reads out [of a claim] a preferred embodiment 'is rarely, if ever, correct and would require highly persuasive evidentiary support.'" *Amgen*, 314 F.3d at 1349 (internal citation omitted). Harman cannot carry its heavy burden to overcome the teaching of the preferred embodiment.

6. "a speech generator functionally connected to said discourse generator for generating speech from said discourse provided by said discourse generator,"

Counsel for Harman advised MIT *today* that Harman does not intend to dispute MIT's proposed construction of "speech generator." MIT believes the proper construction is "A system capable of receiving output from the discourse generator and converting the output into an electronic signal which will generate speech in the voice apparatus."

However, the parties seem to disagree over what is meant by MIT's construction because MIT understands Harman's position to be that its navigation systems do not have a "speech generator." There is no dispute that Harman's navigation systems can speak the driving instructions to the driver after the appropriate instructions have been determined by the "discourse generator" of Harman's systems. MIT's construction is not limited to the particular form of the output received from the "discourse generator" because the content of the spoken messages has already been determined by the "discourse generator." The speech generator converts the intended message into something audibly deliverable to the driver.

The patent specification discloses a "speech generator" which receives the output of the discourse generator and "conveys them to the driver by means of a speaker system [voice

apparatus]." Exh. 1 at Figure 1; 3:40-41. During his deposition, inventor Chris Schmandt described the technical difference between the discourse generator and the speech generator:

> A discourse generator figures out what to say…It figures out in some context, subject to some limitations, what to say. It generates output in some form. In the case of Back Seat Driver, this was text. It could be other forms, which goes to a speech generator, which is something that can take that intermediate form and turn it into an audio wave form, which acoustically is speech or close to speech.

Exh. 20 at 233:10-19.

In the working prototype, a DECtalk text-to-speech synthesizer was used to generate speech. Exh. 1 at 23:40-43. In this one embodiment, the output of the discourse generator was a text-string that the DECtalk accepted and "read" by sending an audio signal to a speaker which spoke the instructions. Exh. 1 at 23:59-61. Speech synthesizers can also concatenate speech fragments or portions of speech output to form messages rather than receiving full-text output. Such a speech generator would receive either the speech fragments from the discourse generator or an output signal that is converted into an analog signal for delivery to the voice apparatus by the speech generator.

The patent specification discloses a speech generator capable of using "digitized speech" where speech fragments or coded speech would be stored in a database (e.g., on a CD-ROM containing the map database). In such a system, "fragments of instructions are stored digitally and retrieved from storage" before being sent to the voice apparatus. Exh. 21 at ¶ 41.[5] In such an embodiment, the output of the discourse generator would be a digital speech fragment or a

[5] Although the Expert Report of Richard A. Belgard is marked "Highly Confidential" in its entirety, the excerpts contained in Exhibit 21 do not contain the confidential information of either party.

reference to the coded speech in the speech database, and the speech generator would retrieve the speech fragment and send a signal to the audio speaker for generating the spoken instruction.

B. Claim 45

The automobile navigation system of claim 1 wherein said discourse generated comprises a long description of an act given substantially before the act is to be performed and a short description given *at the time the act is to be performed*.

The parties disagree over the proper construction of "at the time the act is to be performed." MIT asserts that "at the time the act is to be performed" describes a relative timing of the description. That is, taking into account all of the information the system has regarding the route and speed of the automobile, an instruction is provided in time for the driver to safely hear the instruction and react to it. Harman's proposed construction for "at the time the act is to be performed" requires that the direction be given "at the <u>instant</u> the driver is required to act."

Terms to be Construed	MIT's Construction	Harman's Construction
"at the time the act is to be performed"	at the time the act is to be performed" describes relative timing of the short description in reference to the driving act and the long description. This phrase does not require the short description to be given at the instant the act should be performed. Instead, the short description can occur in, on, or near the location on the route at which the act is to be performed or shortly before the driver is required to act.	at the instant the driver is required to act.

The specification describes in detail that an object of the invention is to reduce demands on the driver's mental faculties (e.g., attention) by producing sophisticated spoken output that allows the driver to react to the instructions in time to appropriately act. Exh. 1 at 1:47-50;

18:19-31. Harman's construction would require an infringing automobile navigation system to abruptly inform the driver that a maneuver is *immediately required* and not before, without providing sufficient time for the driver to contemplate or process the instruction without missing the maneuver.

MIT's proposed construction for this element accounts for the inventors' reasons for inventing the Back Seat Driver system, namely, providing instructions to the driver "just in time" for the driver to safely respond to the instruction. Exh. 8 at 2. Most often, the time at which the short description begins will be less than "a few seconds" before the action is to occur. Exh. 1 at 16:41. The patent specification indicates that the instruction should be provided *before* the instant the driver is required to act:

> Besides telling drivers what to do, the Back Seat Driver must also tell them when to do it. One way to do this is by speaking at the moment to act, *but it is useful to also give instructions before the act*, if time permits. This allows time for preparation, if required…and also *spares the driver the need to be constantly alert for a command which must be obeyed at once.*

Exh. 1 at 16:33-40 (emphasis added).

MIT's proposed construction for "at the time the act is to be performed" also accounts for the existence of the "long description" which can be given "[w]hen an act is more than a few seconds in the future." Exh. 1 at 16:41. Therefore, MIT submits that its proposed construction more properly aligns with the patent specification, what the inventors invented and common sense.

Harman has proposed a construction for this element comes from the portion of the patent specification relating to the "Location System and Position Sensor." Harman suggests that the short description must be given "at the latest time that still permits the driver to act." Exh. 19 at 4. However, Harman's definition runs counter to the plain meaning of the claim and as described in the patent specification.

VI. CONCLUSION

MIT's proposed constructions for the claim language of the '685 patent are consistent with established principles of claim construction, and should be adopted by the Court.

March 30, 2007

Respectfully Submitted,

Massachusetts Institute of Technology,
By its Attorneys,

/s/ Steven M. Bauer
Steven M. Bauer (BBO# 542531)
Jacob K. Baron (BBO# 652568)
Kimberly A. Mottley (BBO# 651190)
John W. Pint (BBO# 660548)
PROSKAUER ROSE LLP
One International Place
Boston, Massachusetts 02110-2600
Phone: 617-526-9600
Fax: 617-526-9899

REQUEST FOR ORAL ARGUMENT
PURSUANT TO LOCAL RULE 7.1(D)

MIT respectfully requests oral argument on the claim interpretation issues discussed in this brief.

CERTIFICATE OF SERVICE

I certify that on March 30, 2007, I caused a copy of the forgoing document to be served upon counsel of record for Harman International Industries by electronic mail and Federal Express overnight delivery.

/s/ Steven M. Bauer
Steven M. Bauer

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF MASSACHUSETTS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Plaintiff, v. HARMAN INTERNATIONAL INDUSTRIES, INCORPORATED, Defendant.	Civil Action No.: 05-10990 DPW Magistrate Judge Judith G. Dein

DECLARATION OF JOHN W. PINT

I, John W. Pint, state:

1. I am an associate with the law firm of Proskauer Rose LLP, counsel for plaintiff Massachusetts Institute of Technology ("MIT"). I am familiar with the facts of the above-captioned case.

2. I make this declaration for the sole purpose of providing the Court copies of certain documents which are attached to and referred to in the MIT's Opening Memorandum On Claim Construction.

3. Exhibit 1 is a true copy of U.S. Patent No. 5,177,685, entitled "Automobile Navigation System Using Real Time Spoken Driving Instructions" in the name of inventors James R. Davis and Christopher M. Schmandt, assigned to MIT, and issued January 5, 1993.

4. Exhibit 2 is a true copy of excerpts from Technical Memo 1 of the Speech Resource Group at the MIT Media Laboratory, authored by James Raymond Davis and Thomas Frank Trobaugh, titled "Direction Assistance," and dated December 1987.

5. Exhibit 3 is a true copy of excerpts from the Rebuttal Expert Report of Barbara J. Grosz, Ph.D., dated August 22, 2006.

6. Exhibit 4 is a true copy of excerpts from the Rebuttal Expert Report of Lynn A. Streeter, Ph.D., dated August 22, 2006.

7. Exhibit 5 (filed under seal) is a true copy of excerpts from the deposition testimony of Robert L. French, which took place September 15, 2006.

8. Exhibit 6 is a true copy of the Expert Report of Robert French, dated July 18, 2006.

9. Exhibit 7 is a true copy of excerpts from U.S. Patent Application No. 10/528,526, titled "Navigation System With Acoustic Route Information," filed on February 24, 2003, assigned to Harman-Becker Automotive Systems GmbH, and published as Patent Publication No. US 2006/0031009 on February 9, 2006.

10. Exhibit 8 is a true copy of excerpts from Dr. James R. Davis' Ph.D. thesis titled "Back Seat Driver: voice assisted automobile navigation," dated September 1989, and publicly available in February 1990.

11. Exhibit 9 is a true copy of excerpts from the Expert Report of Barbara J. Grosz, Ph.D., dated July 18, 2006.

12. Exhibit 10 is a true copy of excerpts from the Expert Report of Dr. Diane J. Litman, dated August 4, 2006.

13. Exhibit 11 is a true copy of excerpts from Rebecca J. Passonneau & Diane J. Litman, <u>Empirical Analysis of Three Dimensions of Spoken Discourse: Segmentation, Coherence, and Linguistic Devices</u>, Chapter 7 of *Computational and Conversational Discourse* (Eduard H. Hovy & Donia R. Scott eds. 1993).

14. Exhibit 12 is a true copy of excerpts from Rebecca J. Passoneau & Diane J. Litman, Discourse Segmentation by Human and Automated Means, Computational Linguistics vol. 23, no. 1 (1997).

15. Exhibit 13 is a true copy of excerpts from Technical Memo 2 of the Speech Resource Group at the MIT Media Laboratory, authored by James Raymond Davis, titled "A voice interface to a Direction giving program," and dated January 1987.[1]

16. Exhibit 14 is a true copy of excerpts from Merriam-Webster's Collegiate Dictionary (10th ed. 2002).

17. Exhibit 15 is a true copy of excerpts from The American Heritage College Dictionary (4th ed. 2002).

18. Exhibit 16 (filed under seal) is a true copy of excerpts from the Rebuttal Expert Report of Robert French, dated August 22, 2006.

19. Exhibit 17 is a true copy of excerpts from the U.S. Patent & Trademark Office file history of U.S. Patent No. 5,177,685.

20. Exhibit 18 is true copy of the definition of "consult" from WordNet 2.1 of Princeton University.

21. Exhibit 19 is a true copy of a letter from Jamal M. Edwards to Jacob K. Baron, dated March 2, 2007.

22. Exhibit 20 is a true copy of excerpts from the Expert Report of Richard A. Belgard, dated July 17, 2006.

23. Exhibit 21 is a true copy of excerpts from the deposition testimony of Christopher M. Schmandt, which took place February 8, 2006.

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[1] Although this document bears a January 1987 date, upon information and belief, the document should bear an April 1988 date. See Exh. 8 at 158 n. 18.

I declare under penalty of perjury that the foregoing is true and accurate and that this Declaration was executed on March 30, 2007.

/s/ John W. Pint
John W. Pint

EXHIBIT 1

US005177685A

United States Patent [19]

Davis et al.

[11] Patent Number: 5,177,685

[45] Date of Patent: Jan. 5, 1993

[54] **AUTOMOBILE NAVIGATION SYSTEM USING REAL TIME SPOKEN DRIVING INSTRUCTIONS**

[75] Inventors: James R. Davis, North Cambridge; Christopher M. Schmandt, Milton, both of Mass.

[73] Assignee: Massachusetts Institute of Technology, Cambridge, Mass.

[21] Appl. No.: 565,274

[22] Filed: Aug. 9, 1990

[51] Int. Cl.[5] G01C 21/00

[52] U.S. Cl. 364/443; 340/988; 364/449; 364/453

[58] Field of Search 340/988, 989, 990, 995; 364/443, 444, 449, 450, 453, 436

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"Attention, Intentions, and the Structure of Discourse", by B. J. Grosz and C. L. Sidner (Computational Linguistics, 12(3):175-204, 1986.

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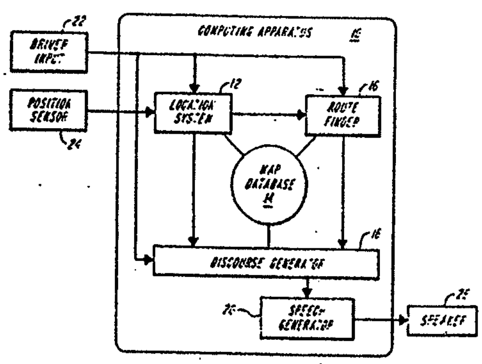
Primary Examiner—Parshotam S. Lall
Assistant Examiner—Edward Pipala
Attorney, Agent, or Firm—Choate, Hall & Stewart

[57] ABSTRACT

An automobile navigation system which provides spoken instructions to the driver of an automobile to guide the driver along a route is disclosed. The heart of the system is a computing apparatus comprising a map database, route finding algorithms, a vehicle location system, discourse generating programs, and speech generating programs. Driver input means allows the driver to enter information such as a desired destination. The route finding algorithms in the computer apparatus calculate a route to the destination. The vehicle location system accepts input from a position sensor which measures automobile movement (magnitude and direction) continuously, and using this data in conjunction with the map database, determines the position of the automobile. Based on the current position of the automobile and the route, the discourse generating programs compose driving instructions and other messages according to a discourse model in real time as they are needed. The instructions and messages are sent to voice generating apparatus which conveys them to the driver.

58 Claims, 3 Drawing Sheets



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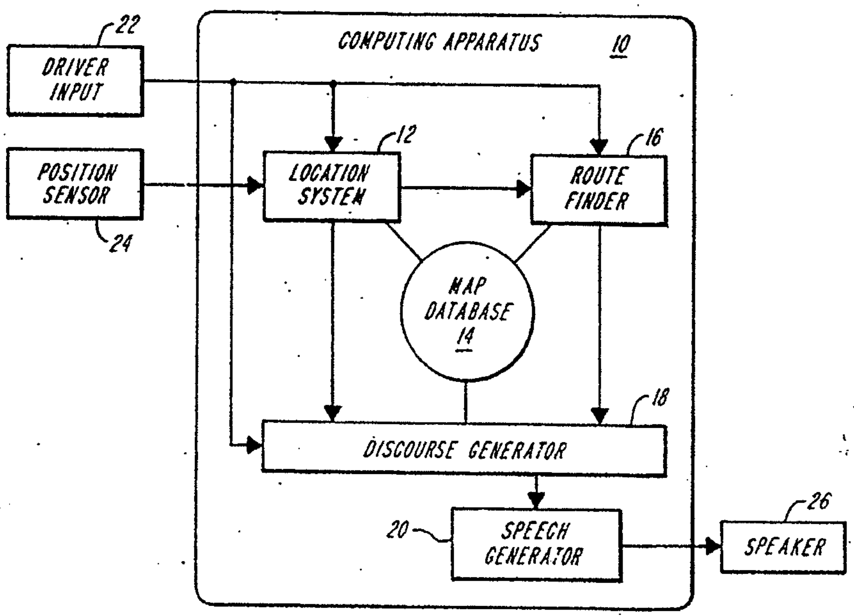
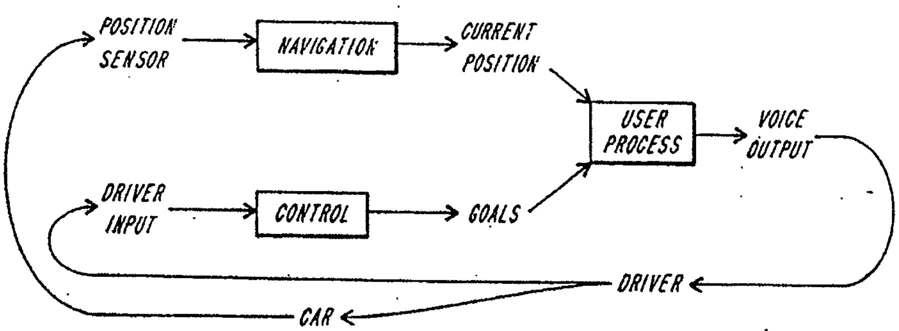


COMPUTING APPARATUS
10
22
DRIVER INPUT
POSITION SENSOR
24
LOCATION SYSTEM
12
ROUTE FINDER
16
MAP DATABASE
14
18
DISCOURSE GENERATOR
20
SPEECH GENERATOR
26
SPEAKER

FIG. 1



POSITION SENSOR
NAVIGATION
CURRENT POSITION
USER PROCESS
VOICE OUTPUT
DRIVER INPUT
CONTROL
GOALS
DRIVER
CAR

FIG. 2

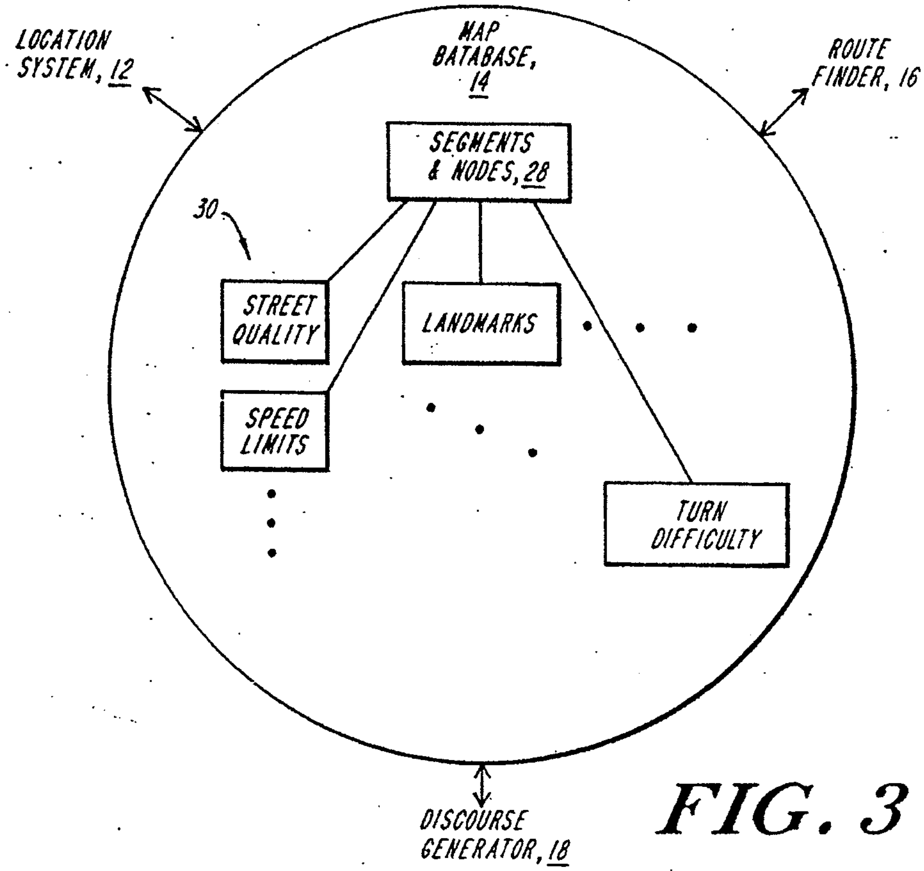

LOCATION SYSTEM, 12
MAP DATABASE, 14
ROUTE FINDER, 16
SEGMENTS & NODES, 28
30
STREET QUALITY
LANDMARKS
SPEED LIMITS
TURN DIFFICULTY
DISCOURSE GENERATOR, 18

FIG. 3

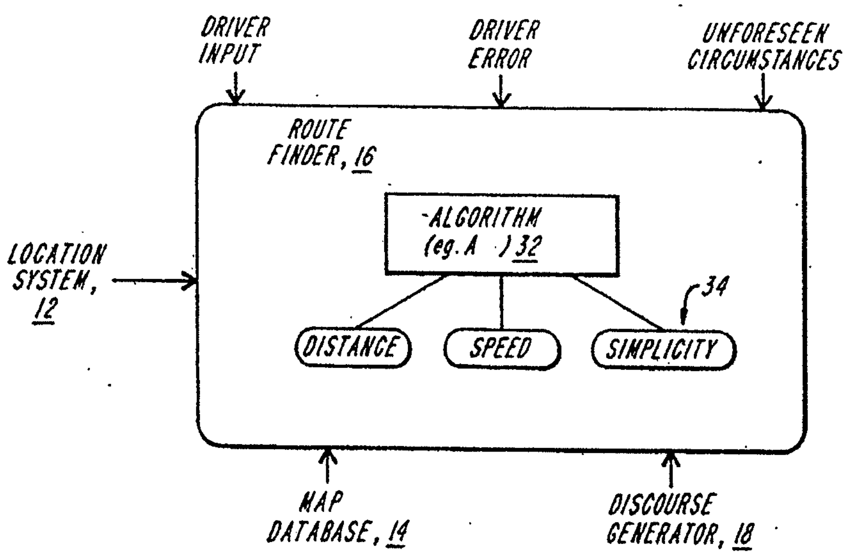
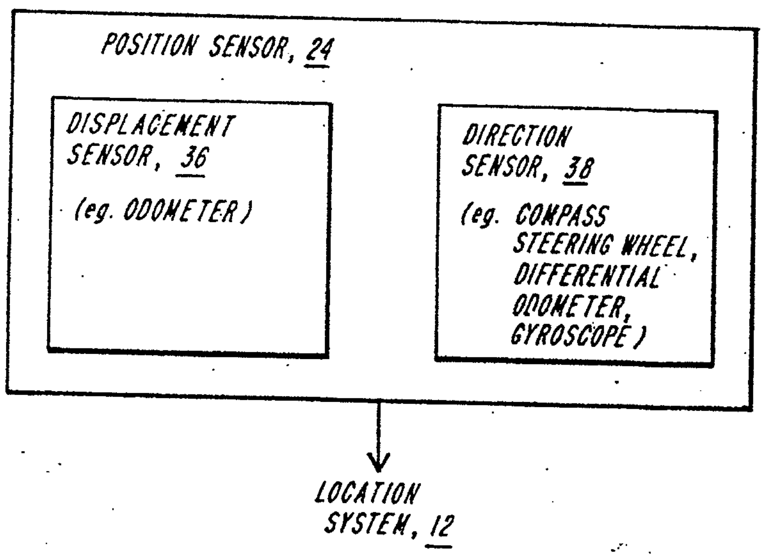

DRIVER INPUT
DRIVER ERROR
UNFORESEEN CIRCUMSTANCES
ROUTE FINDER, 16
ALGORITHM (eg. A) 32
LOCATION SYSTEM, 12
34
DISTANCE
SPEED
SIMPLICITY
MAP DATABASE, 14
DISCOURSE GENERATOR, 18

FIG. 4



POSITION SENSOR, 24
DISPLACEMENT SENSOR, 36
(eg. ODOMETER)
DIRECTION SENSOR, 38
(eg. COMPASS STEERING WHEEL, DIFFERENTIAL ODOMETER, GYROSCOPE)
LOCATION SYSTEM, 12

FIG. 5

AUTOMOBILE NAVIGATION SYSTEM USING REAL TIME SPOKEN DRIVING INSTRUCTIONS

BACKGROUND OF THE INVENTION

This invention relates to computerized automobile navigation systems, particularly to a system which calculates a route to a destination, tracks automobile location, and provides spoken instructions to the driver in real time as they are needed.

Navigation systems can be classified into three categories:

Positioning systems tell you where you are.

Orienting systems show the direction of your destination.

Instructional systems tell you what to do to get to your destination.

A navigation system can provide one, two, or all of these services. Navigation systems can be further distinquished by how they provide the information:

Verbal systems speak.

Textual systems provide text.

Graphic systems provide pictures.

Finally, systems can be classified as either real time or static. The categories of this classification are not independent. There can be no static positioning system, since one cannot predict the future position of an automobile.

There are several problems with static navigation systems. First, they do not help the driver follow the route. The driver must determine when to apply each instruction. A second problem is that since the instructions must be specified in advance, there is little to be done if the driver does not follow the instructions, which might happen from error, or because the instructions are wrong, or simply ill-advised (as when confronting a traffic jam).

Previous automobile navigation systems have used text or graphics to give navigation information. However, there are several disadvantages to presenting information visually. First, the driver must look at a display while driving, which makes driving less safe. For providing driving directions, visual displays are most easily used when they are least needed. Second, with respect to graphic displays, many people have difficulty using maps, making this mode of providing information undesirable. However, if speech is used, the driver's eyes are left free for driving. In addition, speech uses words, and can therefore refer to past and future actions and objects not yet seen. This is hard to do with symbolic displays or maps.

There is clearly a need for an instructional, verbal, real time automobile navigation system which can guide a driver to a destination much as a passanger familiar with the route would. The present invention meets that need.

SUMMARY OF THE INVENTION

The present invention, called the "Back Seat Driver", is a computer navigation system which gives spoken instructions to the driver of an automobile to guide the driver to a desired destination. Computing apparatus, installed either in the automobile or accessed through a cellular car phone, contains a map database and a route finding algorithm. A vehicle location system uses data from a position sensor installed in the automobile to track the location of the automobile. Discourse generating programs compose driving instructions and other messages which are communicated to the driver using voice generating apparatus as the driver proceeds along the route.

The important differences between The Back Seat Driver and other such systems are that the Back Seat Driver finds routes for the driver, instead of simply displaying position on a map, tells the driver how to follow the route, step by step, instead of just showing the route, and speaks its instructions, instead of displaying them. Each of these design goals has required new features in the programs or in the street map database.

The street map database of the Back Seat Driver distinguishes between physical connectivity (how pieces of pavement connect) and legal connectivity (whether one can legally drive onto a physically connected piece of pavement). Legal connectivity is essential for route finding, and physical connectivity for describing the route.

To find the fastest routes, the map database of the Back Seat Driver includes features that affect speed of travel, including street quality, speed limit, traffic lights and stop signs. To generate directions, the map includes landmarks such as traffic lights and buildings, and additional descriptive information about the street segments, including street type, number of lanes, turn restrictions, street quality, and speed limit. The map also preferably includes other features, such as time-dependent legal connectivity, and expected rate of travel along streets and across intersections. Positions are preferably stored in the map database in three dimensions, not two, with sufficient accuracy that the headings of the streets can be accurately determined from the map segments.

Driving instructions generated by the Back Seat Driver are modeled after those given by people. The two issues for spoken directions are what to say (content) and when to say it (timing). The content of the instructions tells the driver what to do and where to do it. The Back Seat Driver has a large taxonomy of intersection types, and chooses verbs to indicate the kind of intersection and the way of moving through it. The instructions refer to landmarks and timing to tell the driver when to act.

Timing is critical because speech is transient. The Back Seat Driver gives instructions just in time for the driver to take the required action, and thus the driver need not remember the instruction or exert effort looking for the place to act. The Back Seat Driver also gives instructions in advance, if time allows, and the driver may request additional instructions at any time. If the driver makes a mistake, the Back Seat Driver describes the mistake, without casting blame, then finds a new route from the current location.

Giving instructions for following a route requires breaking the route down into a sequence of driving acts, and knowing when an act is obvious to the driver and when it needs to be mentioned. This further requires knowledge about the individual driver, for what is obvious to one may no be so to another. The Back Seat Driver preferably stores knowledge of its users, and uses this knowledge to customize its instructions to the preferences of the users.

Speech, especially synthetic speech, as an output media imposes constraints on the interface. The transient nature of speech requires that utterances be repeatable on demand. The Back Seat Driver has the ability to construct a new utterance with the same intent, but not necessarily the same words, as a previous message.

Synthetic speech being sometimes hard to understand, the Back Seat Driver chooses its words to provide redundancy in its utteranaces.

An actual working prototype of the Back Seat Driver has been implemented. It has successfully guided drivers unfamiliar with Cambridge, Mass. to their destinations. It is easy to foresee a practical implementation in the future.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 illustrates schematically the basic functional components of the Back Seat Driver in its preferred embodiment.

FIG. 2 illustrates the system processes of the preferred embodiment of the Back Seat Driver.

FIG. 3 is a schematic illustration of the map database.

FIG. 4 is a schematic illustration of the route finder.

FIG. 5 is a schematic illustration of the position sensor.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The automobile navigation system according to the present invention is illustrated schematically in FIG. 1. The heart of the system is a computing apparatus 10 comprising a vehicle location system 12, a map database 14, a route finder 16, a discourse generator 18, and a speech generator 20. Driver input means 22 allows the driver to input to the computing apparatus 10 information such as a desired destination. A position sensor 24 measures automobile movement (magnitude and direction) and sends data to the location system 12 which tracks the position of the automobile on the map. The route finder 16 calculates a route to the destination. Based on the current position of the automobile and the route, the discourse generator 18 composes driving instructions and other messages according to a discourse model in real time as they are needed. The instructions and messages are sent to the speech generator 20 which conveys them to the driver by means of a speaker system 26. The speaker system may be that of the car's radio.

In FIG. 1, the computing apparatus is illustrated as a single entity. However, in other embodiments, the components may not all be implemented in the same piece of apparatus. For example, in one working prototype of the Back Seat Driver, the main computing apparatus is a Symbolics Lisp machine, but the location system is implemented separately by an NEC location system that tracks the position of the automobile using its own map database, and the speech generator is implemented separately by a Dectalk speech synthesizer. In another working prototype, the main computing apparatus is a Sun Sparc workstation. The map database for the Back Seat Driver can be provided on a CD-ROM, a floppy disk, or stored in solid-state memory, for example.

The components of the system and the system processes which coordinate their performance, particularly as embodied in the working prototypes, are discussed in the sections which follow. Aspects of the invention are also described in the following sources, which are hereby incorporated by reference:

1. "Synthetic speech for real time direction-giving," by C. M. Schmandt and J. R. Davis, *Digest of Technical Papers, International Conference on Consumer Electronics*, Rosemont, Ill., Jun. 6-9, 1989.
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3. "The Back Seat Driver: Real time spoken driving instructions," by J. R. Davis and C. M. Schmandt, *Proceedings of the IEEE Vehicle Navigation and Information Systems Conference*, Toronto, Canada, September 1989.
4. "Back Seat Driver: Voice assisted automobile navigation," by J. R. Davis, Ph.D. thesis, Massachusetts Institute of Technology, September 1989.

MAP DATABASE

The map database for the Back Seat Driver in the working prototypes originated as a DIME (Dual Indepedent Map Encoding) file, a map format invented by the U.S. Census Bureau for the 1980 census. Implementing the Back Seat Driver required extending the DIME map format in a number of ways to make it useful for route finding and route describing.

The basic unit of the DIME file is the segment. A segment is a portion of a street (or other linear feature such as a railroad, property line, or shoreline) chosen to be small enough that it is a straight line and has no intersection with any other segment except at its endpoints.

The two endpoints of a segment are designated FROM and TO. If the segment is a street segment (as opposed to, say, a railroad) and has addresses on it, then the FROM endpoint is the one with the lowest address. Otherwise, the endpoint labels are chosen arbitrarily. A segment has two sides, left and right. The sides are chosen with respect to travel from the FROM endpoint to the TO endpoint. A navigator using a DIME file can find the location of an address along the segment by interpolating the addresses between the low and high addresses for the two endpoints. The DIME file is suited to determining the approximate position of a building from its street address.

Attributes of a DIME file segment include: its name (40 characters), its type (a one to four character abbreviation such as "ST"), the ZIP code for each side, and the addresses for each endpoint and each side. At each endpoint of a segment is a pointer to a node. A node represents the coordinates of that endpoint and the set of other segments which are physically connected at that endpoint. Segments share nodes. If any two segments have an endpoint at the same coordinate, they will both use the same node for that endpoint.

A vehicle navigation system using a DIME file can represent the position of a vehicle on the map by a structure called a position. A position has three parts: a segment, an orientation, and a distance. The segment is one of the segments from the map database, the orientation specifies the direction the vehicle is travelling (towards the TO or FROM endpoint), and the distance is the distance from the FROM endpoint of the segment, no matter which way the vehicle is oriented. When travelling towards the TO endpoint of the segment, distance increases, when travelling towards the FROM endpoint, it decreases.

The DIME file is not adequate for routing finding and is only marginal for generating route descriptions. The most important problem with the DIME format is that it indicates only if two segments are physically connected (that is, if they touch), but not whether they are legally connected (i.e. whether it is legal to travel from one to the other). Legal connectivity is crucial for route finding. However, legal connectivity does not

replace physical connectivity; route description requires information about physical connections as well. Physical connectivity also affects route finding directly when seeking the simplest route, since ease of description is determined in part by physical connectivity.

The most significant extension of the DIME file format required for its use in a vehicle navigation system is the explicit representation of legal connectivity. This can be accomplished by adding a legal connection list at each endpoint of a segment to indicate all segments which are legally accessible from that endpoint. This allows the route finder to consider only legal paths. To the inventor's knowledge, this has not been included in any other navigation system.

Another problem with the DIME file is that it is a planar graph. This means that no two segments can cross except at an intersection, so there is no way to correctly represent an overpass, for example. The DIME format represents an overpass by breaking both streets at the point where they cross, and creating a fictitious intersection even though the segments do not touch in reality. These false intersections are particularly troublesome since DIME does not represent legal connectivity, so it appears possbile and legal for a car to jump straight up and turn onto the overpass.

Points in the map database for a vehicle navigation system are therefore preferably three-dimensional. Route descriptions then provide better knowledge of the underlying topography. Stopping distance is affected by slope, so instructions must be given sooner when traveling down a hill. Slope affects safety. The route finder should avoid steep slopes in snowy weather. Finally, distance between points will be more accurate when change in altitude is considered. Roads designed for high speed may be more level than the underlying topography. They may be elevated or they may be depressed. A road which is not at grade will not have the slope of the land beneath it.

Coordinates in the DIME file are stored in ten thousandths of a degree. This means that the position of an endpoint in the map differs form the true position by as much as 6.5 meters in latitude and 5 meters in longitude at the latitude of Boston. This inherent position error causes problems because it introduces error in length and in heading. Uncertainty in heading causes uncertainty in the angle between two segments. A straight street can appear to wobble if it is made of many short segments. Segment "wobble" causes problems for a route finder, makes it hard to generate correct descriptions, and interferes with position determination.

DIME file segment "wobble" can be corrected for by assuming that the angle between two streets is the smallest possible value. However, this sometimes overestimates the speed an intersection can be travelled through. Uncertainty in the angle of segments at an intersection also makes it difficult to describe the intersection correctly and interferes with navigation because it makes it difficult to compare compass headings with the heading of a street.

A richer taxonomy of street types than that provided by DIME is preferable for a vehicle navigation system. Important categories of streets are: ordinary street, rotary, access ramp, underpass, tunnel, and bridge. Preferably, non-streets such as railroad, water, alley and walkway are also included.

The DIME file records a small amount of information about each segment. For a vehicle navigation system, additional attributes are preferably added to make better descriptions. Important additional attributes are street quality, divided roads, signs, traffic lights, stop signs, buildings, other landmarks, lane information, and speed limit.

The street quality can be, for example, a number from 1 ("super") to 4 ("bad") which combines the ease of locating and following the street and the expected rate of travel along it. The street quality attribute should be used by both the route finder and the route describer.

The identification of divided roads is necessary to avoid U Turns where they are not possible, although it is preferable to make U Turns only if there is no other alternative. In addition, the route finder should recognize that a divided road is safer than an undivided road.

Sign and exit numbers are preferably stored in the map database as connection cues, which are text strings that give cues for moving from one segment to another. Every cue has a type which tells the kind of cue, e.g. sign or exit-number. There may be more than one connection cue for a given pair of segments, but there should never be more than one of a type.

The most useful landmarks are traffic lights. Traffic lights are preferably stored independently for each endpoint of each segment, since the presence of a light at one segment of an intersection does not imply that all other segments at the intersection have a light.

Two types of buildings which are especially useful as landmarks are toll booths and gas stations. Toll booths can be stored as connection cues. Gas stations can be stored in the services database described below. However, a preferred approach is to index gas stations (and other buildings) by street.

Roads often have more than one lane. Selecting the proper lane can make travel faster, and it may even be mandatory, since certain turns may only be possible from some lanes. The map database therefore preferably contains the number of lanes for both directions on a segment, and whether one or more lanes is reserved for turn restrictions.

The map database also preferably includes time dependent legal connectivity. Sometimes a given turn will be prohibited at certain hours of the day, typically rush hour. Additionally, lanes sometimes switch direction during the day to accomodate rush hour traffic, and some lanes are reserved for carpools during rush hour.

The expected rate of travel is not necessarily a function of street quality. Although there is a correlation, travel rate is preferably a separate segment attribute. One reason is that travel rate, unlike quality, changes during the day. A model of traffic flow like that of an experienced driver (i.e. it should know what "rush hour" means) is preferably implemented in the map database.

Some turns, though legal, are difficult to make. The route finder preferably avoids these turns if possible. To an extent, the difficulty of a turn is implicit in the quality of the participating street segments, but an explicit model in the map database is preferred.

Some lanes or streets are restricted to certain kinds of traffic (car pools, no commerical vehicles). Also important are height restrictions, since some underpasses are so low that tall vehicles will not fit under them. This information is preferably included in the map database.

At some lights it is permitted to make a right turn at a red light after a full stop. Right turns here will be no slower than rights turns at a stop sign, so the route finder should prefer such intersections to those that do not permit it. Also, traffic lights have differing cycle

lengths. The map database preferably includes this information.

Local knowledge is also preferably included in the map database. These are facts about how people and institutions act on or near the road; e.g. that a speed trap is here, or that this road is one of the first ones plowed after a snow storm.

The Back Seat Driver should allow the driver to select famous destinations by name in addition to address by including this information in a database, and this database should be integrated with the services database, discussed below. The Back Seat Driver should also support names of buildings and office plazas made up by developers without reference to the street names.

Service locations are preferably stored in a services database. This database lists services such as gas stations, automatic teller machines and stores. For each service is recorded the name of the establishment, the address, phone number, and hours of operation. This allows the Back Seat Driver to select the closest provider of a service known to be open. The database can also be used as a source of landmarks when giving directions.

The map database preferably contains information on the division of the city into neighborhoods. This is useful for selecting an address. The postal ZIP code is not good for classifying neighborhoods.

Pronunciation information is preferably stored in a database for those place names which are easily mispronounced by the speech synthesizer. It would also be desirable to record which of those names have unusual spellings. This would allow the system to warn the driver to be alert for signs that might otherwise surprise her. Note that the driver only hears the name of a street, and has to guess how it is spelled from the sound she hears.

Abbreviations are preferably included to allow the user to enter certain street names in abbreviated form. A second use for abbreviations is to supply alternate spellings for streets, for example, to allow the driver to spell "Mt Auburn" as "Mount Auburn".

An almanac is preferably included to list the time of sunrise and sunset for the city. Arrangements can be made to either purchase this database or locate a program which an calculate it, for arbitrary position and date.

A problem for a practical Back Seat Driver is how to keep the map database accurate, since the streets network is constantly changing. Over time, new street are constructed, old streets are renamed or closed. These kinds of changes are predictable, slow, and long lasting. Other changes are unpredictable, quick, and transient. A road may be closed for repairs for the day, blocked by a fallen tree, or full of snow. Such changes are usually short lived. Thus, the Back Seat Driver needs the ability to change legal connectivity dynamically. In addition, the route finder should preferably have the ability to avoid congested roads caused by rush hour or accidents, for example. The map database is therefore preferably continuously updated by some form of radio broadcast by an agency that monitors construction and real time traffic conditions.

The Census Bureau, in cooperation with the United States Geological Survey, has designed a new map format known as TIGER (Topologically Integrated Geographic Encoding and Referencing) which has several improvements over the DIME format, but which is still a planar graph representing only physical connectivity. The map database for a Back Seat Driver could be also be originated from a TIGER file as long as the extensions discussed above were implemented.

The map database is shown schematically in FIG. 3. In the preferred embodiment, the map database 14 includes, as its basis, a file 28 of segments and nodes. File 28 may be an original file or may be adapted from a DIME file or a TIGER file by adding the above-described extensions. In addition, the map database 14 may include optional features 30, as described above.

ROUTE FINDER

Finding a route between two points in a street network is an example of searching a general graph. The task is to find a sequence of segments that lead from the origin to the destination. There are usually a great many distinct ways of getting from one place in the city to another, some better than others. Graph search algorithms differ in the quality of the solution they find and the time they require. The Back Seat Driver requires an algorithm that finds a good route in a short time.

The route finder of the working prototypes of the Back Seat Driver is based on an A* search algorithm. The A* algorithm is a form of best-first search, which itself is a form of breadth-first search. These searching techniques are well-known and are described in detail in Davis, 1989, cited above.

In a breadth-first search, a tree of all possible decisions is divided into levels, where the first level actions are those leading from the root, the second level actions are those that come from situations after first level actions, and so on. All actions at a given level are considered before any at the next higher level. While the breadth-first search is operating, it maintains a list of all possible partial routes and systematically examines every possible path from the end of every partial route to compile a new list of partial routes. This search procedure finds the path with the fewest segments. However, this is not necessarily the best path. To be sure of finding the best path, the search cannot stop when the first path is found, but must continue, expanding each path, until all paths are complete. This is not at all desirable, since there could be (and in fact will be) many paths.

The best-first algorithm solves this problem by keeping track of the (partial) cost of each path, and examining the one with the smallest cost so far. This requires a function that can compare two routes and produce a numeric rating. Such a function is called a metric. To further reduce the cost of searching, before adding a segment to a path, the best-first search checks to see whether it is a member of any other path. If it is, it is not added, for presence on the other path means that the other path was a less expensive way of reaching the same segment.

Best-first search finds the best solution and requires less time than exhaustive breadth-first search, but it still must consider partial solutions with an initial low cost which prove expensive when complete. The A* algorithm avoids wasting time on such falsely promising solutions by including an estimate for the completed cost when selecting the next partial solution to work on. The cost estimate function is $f^*(r)=g^*(r)+h^*(r)$, where r is a route, $g^*(r)$ is the known cost of the partial route, and $h^*(r)$ is the estimate of the cost to go from the endpoint of the route to the goal. The h^* function must have the property of being always non-negative and

never over-estimating the remaining cost. An h* meeting these two conditions is said to be admissible. It should be obvious that if h* is chosen to be always zero, then A* search is just best-first search. In applying A* to finding routes on a map, h* is just the cartesian distance between the endpoint of the partial route and the destination point. It is certain that no route will be shorter than the straight line, so this estimate is never an over estimate. A* search is more efficient than best-first.

The A* algorithm finds the optimum route, but the Back Seat Driver might be better served with an algorithm that finds a reasonable route in less time. This is especially true when the vehicle is in motion. The longer the route finder takes, the greater the distance that must be reserved for route finding. As this distance becomes larger, it becomes harder to predict the future position of the car. This can be done by choosing an h* which multiplies the estimated distance remaining by a constant D. Setting D greater than one makes h* no longer admissible, since the estimate might exceed the actual cost by a factor of D. The resulting routes are no longer optimal, but are still pretty good. The effect is to make the algorithm reluctant to consider routes which initially lead away from the goal.

The route finder preferably uses a value of 2 for D. This yields the greatest increase in payoff. A possible improvement is to run the route finder twice, first with a high value of D to find an initial route in order to begin the trip, and then with a low D to search for a better route, using spare time while driving.

Preferably, three different metrics are used. The distance metric finds the shortest route, the speed metric finds the fastest route, and the ease metric finds the easiest route. The metric for distance is just the sum of the lengths of the component segments. The other two metrics are more complicated than the distance metric, because they must consider intersections as well as segments. In general there is a cost to travel along a segment and a cost to get from one segment to another. All costs are expressed as an "equivalent distance" which is the extra distance one would travel to avoid the cost.

The metric for speed estimates the cost for traveling along a segment by multiplying its length by a constant which depends upon the quality of the street. In principle, one could calculate expected time by dividing length by the average speed on the segment were this quantity available in the database. Examples of appropriate constants are:

Quality	Factor
super	1
good	1.2
average	1.5
bad	2.0

All multiplicative constants must be greater than or equal to one to ensure that the cost of a route is never less than the straight line distance between two points. This condition is essential for the correct operation of the A* search algorithm, since the estimation function (g*) must always return an under-estimate.

The time to cross an intersection is preferably modeled by a mileage penalty which depends upon the nature of the intersection. Examples of appropriate penalties are:

Factor	Cost	Reason
turn	⅛ mile	Must slow down to turn
left turn	⅛ mile	May have to wait for turn across traffic flow
traffic light	⅛ mile	Might be red

If the segment is one-way, the penalties should be cut in half, since there will be no opposing traffic flow. The turning penalties should be computed based only on the angle between two segments, not on the segment type or quality.

The metric for ease seeks to minimize the driver's effort in following the route. Again, driver's effort is the sum of the effort to travel along a segment and the effort to get from one segment to another. Travel along a segment depends upon its quality. Turns of every sort should be penalized equally, since they all require decisions. The intention of this metric is to find routes which require the least amount of speaking by the Back Seat Driver, leaving the driver free to concentrate on other matters.

If the driver leaves the route, the Back Seat Driver must immediately inform the driver and begin to plan a new route. Route planning after a mistake is no different from any other time, except that the vehicle is more likely to be moving. In the working prototypes, when the car is moving, the Back Seat Driver first estimates the distance the car will travel during the route finding process by multiplying the current velocity by the estimated time to find the route. Then it finds the position the driver will reach after traveling this distance, assuming that the driver will not make any turns without being told to do so. It then finds a route from this extrapolated position to the goal. Finally, it finds a route from the car's actual position to the estimated starting position. This second route is so short that the car is unlikely to move far during the time it is computed.

The route finder of the working prototypes estimates the time to find the route between two points by multiplying the distance between them by a constant. This constant was initially determined by running the route finder for 20 randomly selected pairs of origins and destinations. As the Back Seat Driver runs, it accumulates additional values for the constant.

A problem is how to reliably detect when the driver has left the route. With the extended DIME format of the working prototypes, if the driver turns into a gas station, for example, the system will believe, falsely, that the driver has turned onto some street, because the street map includes only streets, and not other paved areas such as parking lots and filling stations. From this false belief, the system will conclude that the driver has made a mistake. However, this problem can be solved by increasing the detail of the map.

Sometimes the driver will choose to not follow a route for good reasons that the Back Seat Driver is unaware of, perhaps because the road is blocked or because of a traffic jam. For the first case, the driver should be provided an "I Can't Do It" button or other means to inform the Back Seat Driver that the road is (temporarily) blocked. Once informed, the Back Seat Driver must automatically find a new route. For the second case, the driver's only recourse is to cancel the current trip (by pushing another button, for example), and, once out of the situation, re-request a route to the original destination. It is essential, though, that the

driver either notify the Back Seat Driver of the impossibility of the requested action or cancel the trip, because otherwise the Back Seat Driver will treat the deviation from the route as a mistake, and continue to attempt to find a new route, which may very well lead back through the street the driver is trying to avoid.

The route finder is shown schematically in FIG. 4. In the preferred embodiment, the route finder 16 includes, as its basis, an algorithm 32. Algorithm 32 may be, for example, an original algorithm based on a best-first search algorithm the A* algorithm, or a modified A* algorithm. In preferred embodiments, the route finder is adapted to find the best route according to any one of three cost metrics 34: distance, speed, simplicity. The route finder calculates a new route in the event of driver error or unforeseen circumstances, as indicated.

LOCATION SYSTEM AND POSITION SENSOR

The Back Seat Driver must know the position of the vehicle. This can be achieved using available technology adapted for the requirements of the Back Seat Driver. At a minimum, the location system for a vehicle navigation system must determine the vehicle position to the nearest block. If it is to tell the driver when to turn, it must be able to distinguish between the closest of two adjacent turns.

Consideration of the Boston street map shows that it has many streets which are both short and a possible choice point. Based on a study of the percentage of segments which are shorter than a given length, an accuracy of 10 meters is desirable. This is a higher accuracy than has been specified in prior art approaches (see Davis, 1989, cited above). The Back Seat Driver's use of speech imposes strict requirements on position because of limitations on time. Unlike a display, speech is transient. An action described too soon may be forgotten. The Back Seat Driver is intended to speak at the latest time that still permits the driver to act. Allowing two seconds for speech, a car at 30 mph covers 27 meters. This consideration suggests a minimum accuracy of 15 meters.

Location systems can be divided into two categories:

Position finding systems determine position directly by detecting an external signal.

Position keeping (dead reckoning) systems estimate the current position from knowledge of an earlier position and the change in position since that position.

All existing position finding systems use radio signals. The broadcast stations may be located on street corners, seacoasts, or in orbit around the earth. Systems differ in their range, accuracy, and cost. A survey of those systems which might plausibly be used for automobile navigation is included in Davis, 1989, cited above.

Position keeping (dead reckoning) systems obtain position indirectly, by keeping track of the displacement from an originally known position. One can measure displacement directly, or measure velocity or acceleration and integrate over time to obtain displacement.

The forward motion of a car is measured by the odometer. On late model cars, the odometer cable has been standardized. It revolves once every 1.56 meters. This is a reliable measure of forward progress, as long as the wheels do not slip. Measuring direction, though, is more difficult. Among the possibilities are:

magnetic compass A magnetic compass has the advantages of small size and ease of use, but is unreliable because of variation between magnetic and true north and deviation due to the ferrous material of the car and magnetic flux arising from electric currents within the car.

steering wheel The steering wheel could be instrumented to measure the amount of turning.

differential odometer When a car turns, the two rear wheels travel different distances, and thus rotate at different rates. Measuring the difference in rotation provides an indication of amount of turning. This differential rate of rotation is just what is measured by anti-skid brakes, so no additional instrumentation is required to obtain this measure for an automobile suitably equiped.

gyroscope Gyroscopes measure angular acceleration. The familiar rotation gyroscope and esoteric laser ring gyroscope are not suitable for automotive use because they are too expensive. Lower cost alternatives are the rate gyro and the gas jet gyro. The rate gyro measures angular acceleration in a vibrating piezo-electric substance. The gas gyro measures turn (or yaw) rate. In this design, a jet of gas travels down the center of a sealed tube. Anemometers are placed on either side of stream. When the car turns, the stream is deflected and the velocity is measured. The velocity of the gas at the anemometer is proportional to the turn rate. Such devices can measure turn rates of up to 100 degrees per second, with a noise of about one half degree/second.

The position sensor is shown schematically in FIG. 5. As indicated, it includes a displacement sensor 36 and a direction sensor 38.

A position keeping system with no error could be calibrated when installed, and then maintain its own position indefinitely. Unfortunately, errors arise in measuring both distance and heading. Sources for error include difference in tire pressure, composition and wear, slipping, cross steering from winds, change in tire contact path in turns, magnetic anomalies, and gyro noise. The NEC dead reckoning system, employed in the prototypes of the Back Seat Driver, accumulates about one meter of error for every ten meters traveled. The error is even worse when traveling near railroads because the NEC system uses a magnetic compass.

Some dead reckoning systems recalibrate themselves to eliminate systematic errors. Such recalibration is possible when the vehicle is at a known position or when stopped. One way to correct dead reckoning errors is to use knowledge of the road network as a constraint on position, in what is known as map matching. Map matching requires that the position keeping system have a map of the locale where the vehicle is being driven, and is based on the assumption that the vehicle is always on a street present in the map. If the estimated position falls to one side of the road, the estimate can be corrected. When the vehicle makes a turn, the system assumes the vehicle is at the closest intersection, and thus the absolute position can be estimated. Every dead reckoning system uses some form of map matching. Map matching reduces the stringency of position keeping, but accuracy remains a concern, since the system must maintain its position when the driver drives off the map, e.g. into a driveway or a parking lot.

In the working prototypes, a unit built by NEC Home Electronics, Ltd. is employed. It is a dead-reckoning position keeping system which uses speed and direction sensors. To compensate for error, it uses map matching on a map database stored on CD-ROM. The unit is described in "CD-ROM Assisted Navigation

Systems" by O. Ono, H. Ooe, and M. Sakamoto, in *Digest of Technical Papers, IEEE International Conference on Consumer Electronics*, Rosemont, Ill., Jun. 8–10, 1988.

As implemented in the working prototypes, the map database used by the location system is completely distinct from the map database used by the route finder and discourse generator. This is unfortunate since the maps will not always agree unless they are kept equally up-to-date. However, in other embodiments within the scope of the invention, the location system uses the computing resources and map database of the main computing apparatus illustrated in FIG. 1. Positioning systems for the Back Seat Driver preferably combine position keeping and position finding, since neither alone will work all the time. A position keeping system needs periodic corrections, but a position finding system that depends on radio reception will not work in tunnels or bridges. Hybrid systems which could be used by the Back Seat Driver are referenced and discussed in Davis, 1989, cited above.

DISCOURSE GENERATOR

The Back Seat Driver attempts to provide instructions to the driver as a passenger in the car familiar with the route would. The content and timing of the instructions and other messages described below are based on a study of natural driving instruction described in detail in Davis, 1989, cited above.

To the Back Seat Driver, a route is a sequence of street segments leading from the origin to the destination. Each connection from one segment to another is considered an intersection, even if there is only one next segment at the intersection. At any moment, the car will be on one of the segments of the route, approaching an intersection. The task of the Back Seat Driver is to say whatever is necessary to get the driver to go from the current segment, across the intersection, to the next segment of the route. Most often, nothing need be said. But at other times, the Back Seat Driver will need to give an instruction.

Instructions must use terms familiar to the driver. An example is what to say at a fork in the road. Considering only topology, there is no difference between a fork and a turn, but it would be confusing to call a fork a turn.

The two key issues in describing a route are deciding what to say and deciding when to say it. There is a tradeoff between these two factors. At one extreme are directions given completely in advance, with no control over when the driver reads them. A direction of this kind might be: "Go half a mile, then take a left onto Mulberry Street". A driver following such an instruction must use the odometer to estimate distance or look for a street sign. The instruction itself does not say when to act. The other extreme are instructions which rely totally on timing for success. Such an instruction might be: "Turn left now".

An intersection type is called an act because the important thing about an intersection is what action the driver takes to get across it. The Back Seat Driver is preferably implemented with an object-oriented programming methodology, so for each act there is an expert (an object) capable of recognizing and describing the act. The Back Seat Driver generates speech by consulting these experts. At any moment, there will be exactly one expert in charge of telling the driver what to do. To select this expert, the Back Seat Driver asks each expert in turn to decide whether it applies to the intersection. The experts are consulted in a fixed order, the most specific ones first. The first expert to claim responsibility is selected. This expert then has the responsibility of deciding what (if anything) to say.

Each act has a recognition predicate which is used to determine if a given intersection should be classified as that act. A predicate can consider topology, geometry, the types of street involved, or any other factor. The predicate also decides whether the move is obvious, that is, the driver can be trusted to do it without being explicitly told to do so. Actions that are obvious are not described. If the next action is obvious, the Back Seat Driver looks ahead along the route until it finds one which is not obvious. There will always be at least one, because stopping at the end is never obvious.

The acts in the working prototypes include CONTINUE, FORCED-TURN, U-TURN, ENTER, EXIT, ONTO-ROTARY, EXIT-ROTARY, STAY-ON-ROTARY, FORK, TURN and STOP.

A CONTINUE is recognized when the driver is to stay on the "same" road. Almost always, a continue is obvious and nothing should be said. The continuation of a street depends on the type of street: from a rotary, it is the next rotary segment; from an access ramp, if there is exactly one next segment, that is the continuation, otherwise there is no obvious next segment; otherwise, it is the one segment that requires no more than 30 degrees of angle change (if there is exactly one, and if it is not a rotary) or the one segment with the same name (if there is exactly one). The reason for comparing names is not because the driver is aware of the name, but because the designer who named the street was. The assumption is that if two segments have the same name, they are the same street, and that is why they have the same name. This "sameness" is presumably reflected in details not captured by the map, for example continuity of painted centerline. There are many places in the area where the obvious "straight" continuation of a segment is at an angle as great as 45 degrees, but it would not be right to call this a turn.

A FORCED-TURN is an intersection where there is only one next street segment where the road bends more than 10 degrees. Even though there is no decision to make at a forced turn, it is useful to mention because it strengthens the driver's sense that the Back Seat Driver really knows about the road conditions. A forced turn is not worth mentioning if both segments are part of a bridge, a tunnel, or an access ramp, or if the angle is less than 20 degrees.

The U-TURN action is recognized when the heading of the car is the opposite of what it should be. Recall that a route is a sequence of segments and endpoints. At all times the car will be on one of the segments in the sequence. If the car's orientation is not the same as the endpoint in the path, then the driver must turn around. Preferably, the route finder only calls for a U Turn if there is no other way.

To ENTER is to move onto a super street (or an access ramp that leads eventually to a super street) from an ordinary street, but not from a super street or an earlier access ramp. Similarly, to EXIT is to move from a super street onto a street with lesser quality that is either an access ramp or has a different name. Some super streets are not uniformly super and it would not be right to call the change in quality an exit.

To go ONTO-ROTARY, to STAY-ON-ROTARY, and to EXIT-ROTARY are acts which can be correctly

described only if the street map database includes an explicit marking of streets as rotaries.

At a FORK, there must be at least two alternatives, all within a narrow angle, and none of the branches must be the obvious next segment—that is, the branches must all be more or less equal. Either all the alternatives must be access ramps, or none of them must be. A branch can only be considered obvious if it is the only branch with the same level of quality, or if it is markedly straighter than the others, or if it is the only one with the same number of lanes, provided that all of these clues agree. If one branch is stronger than the others, the intersection is not a fork. It is either a continue or a turn.

The STOP action is recognized when the vehicle is on the destination segment. Finally, a TURN is an intersection not handled by one of the above cases. The greatest weakness of the above approach is that the recognition predicates are sensitive to small changes in the angles between segments. It is not likely that people use absolute numbers (e.g. 10 degrees) as cut-off values for their determination of how to describe an intersection. More likely, different classifications compete. Still more important, people making classifications use visual cues, not just facts from the map.

Each act has a description function to generate a description of the action. The description function takes inputs specifying the size of the description (brief or long), the tense (past, present or future), and the reference position. A short description is the minimum necessary for the act. It is typically an imperative (e.g. "Bear left."). A long description includes other facts about the action, an expression indicating the distance or time until the act is to be performed, and possibly information about the next act, if it is close. The reference position is a position (along the route) from which the action is to be described.

A brief description consists only of a verb phrase. The verb depends on the type of act and perhaps on the specifics of the act. Besides the verb itself, the verb phrase must say which way to go. In most cases, the word "left" or "right" is sufficient. Where it is not, the possibilities are to use a landmark or to describe the turn. A landmark can be either in the appropriate direction ("towards the underpass") or the other direction ("away from the river"). Specifying direction with a landmark has the advantage that some drivers confuse left and right sides, or mishear the words, so it is a redundant cue. Also, it increases the driver's confidence that the system really knows what the land looks like. A description of the turn can mention either quality or the relative angle of the desired road. The angle must be described qualitatively (more or less "sharp"). It would be more precise to use the angular distance (e.g. "turn right 83 degrees"), but drivers would not understand it. Preferably, the expert for each act follows a protocol which includes:

recognize?—is a proposed movement an example of this kind of driving act?

instruction-vp—generate a verb phrase describing this act

instruction-np—generate a noun phrase describing the act

position-to-doit—the position where the driver would begin carrying out the act

obvious?—would the driver do this act without being told?

sentences—generate all sentences needed to describe this act

congratulate?—should the driver be congratulated after carrying out this kind of act

The following sample is a Back Seat Driver description of the left turn from Fulkerson Street to Main Street in Kendall Square, Cambridge, Mass.:

> Get in the left lane because you're going to take a left at the next set of lights. It's a complicated intersection because there are two streets on the left. You want the sharper of the two. It's also the better of them. After the turn, get into the right lane.

This instruction begins with a piece of lane advice, an action to be taken immediately, then describes an action in the near future. The action is a turn, though that word is not used explicitly. It tells the direction of the turn (left) and specifies a landmark (the lights) that says where the turn is. In many cases, this would be enough, but here there are two streets on the left, so the instruction goes on to specify the desired road in two ways (by comparative position and relative quality). Finally, it concludes with some lane advice to be executed during (or just after) the act.

The above example is the most complicated text that the Back Seat Driver prototypes have produced. Length and detail are not virtues in giving directions. The Back Seat Driver produces a text this long only because it does not have better means to make the driver follow the route. If a shorter text would accomplish the same aim, it would be better.

Besides telling drivers what to do, the Back Seat Driver must also tell them when to do it. One way to do this is by speaking at the moment to act, but it is useful to also give instructions before the act, if time permits. This allows time for preparation, if required, permits the driver to hear the instruction twice, and also spares the driver the need to be constantly alert for a command which must be obeyed at once.

When an act is more than a few seconds in the future, The Back Seat Driver uses a long description, which includes one or more cues which either describe the place for the act, the features of the road between the current location and the place, or the distance or time until the act. This description should be so clear that the driver cannot only recognize the place when it comes, but can also be confident in advance that she will be able to recognize the place.

The Back Seat Driver preferably uses a landmark as a cue when it can. A numeric distance is the cue of last resort. However, some drivers prefer to also hear distances, especially if the distance exceeds a certain threshold. Therefore, a parameter is preferably included in the user-model, described below, for this minimum distance expressed as a number. If the distance is below this, a qualitative phrase is produced by the discourse generator, if above, a number is produced. The cutoff can be zero, in which case numbers are always used, or set to an infinite value, in which case they never are.

A cue is expressed either as a full sentence ("Drive to the end of the street, then . . . ") or a preposed preposition phrase ("At the next set of lights, . . . "). Research has shown that a cue should not be expressed by a preposition after the verb as in "Take a left at the lights." because some drivers start to take the left as soon as they hear the word "left". This may be because syn-

thetic speech does not provide enough intonational cues for the driver to reliably predict the length of the sentence, leading the driver to act on syntactic information alone, and thus taking the sentence to be complete as soon as the word "left" is heard.

The description of a road feature depends upon whether or not it is visible. If it is, it can be referred to with a definite article ("the rotary", "the overpass"). If not, an indefinite article is used. The program cannot tell whether an entity is actually visible, so it uses distance as an approximation. If the feature is closer than one tenth of a mile, it is considered to be visible.

A special case of cues is when the driver is at the place to act. When stopped a few meters from the intersection, it is wrong to say "Turn at the next lights" even if it is literally true. In the working prototypes, the Back Seat Driver thinks of itself as being at that intersection it if its less than thirty yards away, except that if there is a stop light at the intersection and the car is not moving, then the intersection distance if fifty yards, since cars might be backed up at such an intersection. When at an intersection, the Back Seat Driver should say "Take a left here" rather than "Take a left now" because drivers waiting for a traffic light will rightly resent being told to do something they have good reason not to do.

Traffic lights are very good landmarks because they are designed to be easily seen and drivers have an independent reason to watch for them, namely a desire to avoid accidents. When referring to a traffic light, if the car is at the intersection for the lights, the Back Seat Driver should use a proximal deictic ("this" or "these", as opposed to the distal "that" or "those") to show it means the lights that are here.

The Back Seat Driver preferably has a database of buildings as part of its directory of services. If it finds a building on the corner, it should include it as a potential landmark; e.g. "Look for Merit Gas on the left side".

Other landmarks are features of the road, such as underpasses, bridges, tunnels, bends in the road, and railroad crossings. Still another potential landmark is the road coming to an end. This is a landmark that is impossible to miss. However, research has shown that if the Back Seat Driver says "Drive all the way to the end, then . . . ," some drivers take "the end" to mean not "the farthest you can go along this road" but just "the next intersection".

A street name can be a landmark, but not a good one, unless the driver already knows the street. There are several reasons why street names should not be used. First, the driver may not hear the name correctly. Second, the driver may hear the name, but not know how to spell the name after hearing it, so she may not recognize the name in its printed form. This is especially a problem when the driver is from out of town. Finally, even if the driver knows the spelling, street signs are often missing, turned around, or invisible due to weather or darkness. Despite all the problems that come with using street names, many drivers ask for them. To accommodate them, a parameter in the user-model is preferably included to control the use of names. If set, names are supplied as part of the instruction. When names are included, they are preferably attached at the end of the instruction ("Take the second left. It's Elm Street.") rather than directly ("Take the second left onto Elm Street."), which weakens their salience somewhat, and makes them more of a confirmatory cue than an essential one.

Signs can be important landmarks. A problem with using signs as cues occurs, however, if the information in the sign is stored as unstructured text in the map database. It is important that the Back Seat Driver understand what the sign says, not simply utter the words. There are two reasons for this. First, the Back Seat Driver's internal representation for text is preferably based on syntactic structure, not text strings. Second, the objects mentioned in the signs (cities and roads) should be entered into the discourse model to become salient for future reference. The Back Seat Driver should parse sign text by separating it into tokens delimited by commas and the word "and", and then attempt to recognize objects on the map (street names, cities, neighborhoods) from these tokens. When recognition fails, the token cannot be entered into the discourse model. When parsing fails, the spoken output will have incorrect grammar.

The Back Seat Driver does not assume that the driver will recognize the place to act (e.g. by seeing a street sign) so the driver must be told when (or where) to act. The Back Seat Driver uses timing ("Take a left here") when the driver has reached the place to act. The working prototypes calculate the place to speak by finding a distance from the intersection which is $v * (t_{speak} + t_{reaction})$, where t_{speak} is the time to speak the utterance and $t_{reaction}$ is the driver's reaction time. The time to speak depends on the number of words in the utterance. (The Dectalk synthesizer used in the prototypes speaks 180 words per minute.) Reaction time can be estimated to be two seconds.

The Back Seat driver speaks autonomously, but preferably provides means to allow it to speak on demand. The driver at any time should be able to ask for instructions immediately by, for example, pushing buttons representing "What next?" and "What now?". In addition, while following a route, a driver should be able to ask to hear the total length of the route and the remaining distance. A driver should also be able to ask to hear the name of the street the car is on and the compass direction the car is headed.

In order to generate more fluent text, the Back Seat Driver preferably keeps track of what has been mentioned. Some instructions are obvious after having been given. If the system tells the driver to go straight through a set of lights, there is no reason to repeat the instruction when actually at the lights. This is in contrast with a turn, where the driver hears advance instructions to know what to do, and immediate instructions to know when to do it. This can be important, for if the driver hears "go straight through the lights" twice, she may try to go through two sets of lights. To implement this, each instruction should be able to determine whether it is obvious after having been given once. When it is time to speak the instruction, if the instruction has already been given, and it is obvious once spoken, then it should not be spoken again.

The Back Seat Driver preferably retains a history of the route. This allows it to generate cue phrases for the instructions. If the route calls for doing the same thing twice in a row, the system uses the work "another" to indicate this doubling. This is important for polite behavior. If a passenger were to give a driver instructions by just saying "Take a right. Take a right. Take a left. Take a right.", pronouncing each the same, the passenger would be judged to be rude. The passenger's speech is not acknowledging the driver's actions or history. There are two ways for the passenger to acknowledge

the driver's work: using cue words ("Take a right. Take another right. Now take a left."), or using intonation. However, some speech synthesizers, such as the Dectalk used in the prototypes, does not support flexible control of intonation, so cue words are the only possibilty.

The Back Seat Driver preferably is able to warn the driver about dangers which can be inferred from knowledge of the road network. These dangers include driving above the speed limit, driving the wrong way on a one-way street, driving too fast for an upcoming curve, driving on a one-way street that becomes two-way ahead, merging traffic, "blind" driveways ahead, speed traps, poorly repaired roads, potholes, and dangerous intersections. The Back Seat Driver preferably attempts to determine hazards by reasoning about road conditions rather than requiring them to be built in to the map database.

Lane advice includes telling the driver which lane to get into (or stay out of) when applicable. The system gives lane advice as part of the instruction when approaching an intersection where it matters. The instruction may also include advice about what lane to be in after the intersection, in preparation for the next act.

Speed advice includes warning the driver to slow down if she is travelling too fast to safely negotiate a turn. The limiting factor for angular acceleration is the driver, not the cornering ability of the car. Research has shown that the average driver will accept no more an 0.1 G radial acceleration. Radial acceleration is v^2/r where r is the turning radius of the turn. The Back Seat Driver knows the geometry of the road, so it can predict the maximum tolerable velocity for the turn. It need not tell the driver about this speed (the driver will choose a comfortable speed without being told), but it should estimate the distance required to decelerate, and tell the driver to slow down early enough to do this gently.

If the driver leaves the route, the Back Seat Driver immediately informs the driver and begins to plan a new route. Telling the driver what she did wrong prepares her for hearing new instructions, and perhaps helps her learn to better interpret the style of language that the Back Seat Driver uses.

To describe an error, the Back Seat Driver needs to look back to the last action that the driver failed to perform. It should utter a description of this action, saying e.g. "Oops, I meant for you to take a right," which does not blame the driver as in e.g. "You made a mistake. You should have taken a right." A driver might leave the route deliberately; or the error could be system's, not the drivers.

Errors will occur due to inaccuracies in the location system. The Back Seat Driver is preferably able to model the uncertainty of a position. For instance, when two roads diverge at a narrow angle, it will be unable to distinguish which was taken until some distance passes. It should probably assume that the driver made the correct choice rather than taking the risk of making a false accusation. If it reaches a place where the difference is crucial, yet unknown, it is probably better for it to confess its uncertainty, and say something like "I'm not quite sure where we are, but if you can take a right here, do it, and if not, keep going, and I'll figure things out better in a minute." Or it might ask the driver to pull over and stop (if the driver is at a place where that is safe) to allow for a better position estimate by averaging a few successive estimates.

Errors will also occur if the database is somewhat out of date. The Back Seat Driver can regain at least a little confidence by how it explains the mistake. Suppose that the Back Seat Driver intends the driver to turn onto "Apple" Street, and says "Take a right at the next light". Unbeknownst to it, a new traffic light has been installed at "Pear" Street, so the driver turns there. It is somewhat confusing if the Back Seat Driver says "I meant for you to go straight," because the driver may think that the program has not been consistent. A better message would be "I did not mean for you to turn onto Pear. I thought that the next set of lights was at Apple Street."

While the driver is following a route, the Back Seat Driver preferably adopts a persistent goal of keeping the user reassured about her progress and the system's reliability. If the Back Seat Driver were a human, this might be unnecessary, since the driver could see for herself whether the navigator was awake and attending to the road and driver. But the driver cannot see the Back Seat Driver and so needs some periodic evidence that the system is still there. One piece of evidence is the safety warnings the system gives. But if all is going well, there will not be any. Other kinds of evidence that things are going well should be provided. When the user completes an action, the Back Seat Driver can acknowledge the driver's correct action, saying something like "nice work" or "good". Also, insignificant remarks about the roads nearby, the weather and so on, can be provided. The driver then assumes that everything is going well, for otherwise the Back Seat Driver would not speak of trivial matters.

The Back Seat Driver should know about the knowledge and desires of its driver, and act differently because of this knowledge. This knowledge is preferably incorporated in a user-model.

For driver properties which do not change or change very slowly, such as colorblindness, or visual or aural acuity, it is acceptable for the Back Seat Driver to ask the user for such knowledge. However, for other driver properties, the Back Seat Driver preferably acquires a model of the user automatically, without asking or having to be told. For example, the Back Seat Driver could learn the driver's reaction time by measuring the time between its speech and the driver's operation of the controls.

The Back Seat Driver preferably learns the style of instruction giving appropriate for the driver. To learn the driver's preferences for route description requires either observation of the driver herself giving instructions or getting feedback from the driver about the instructions the system provides.

The driver can provide feedback about the suitability of the Back Seat Driver's instructions either explicitly or implicitly. One explicit indication of comprehension is how often the driver hits the "what now?" button. The system might collect long term statistics on the types of intersections where the user most often requests help, and begin to offer instructions without being asked. Just as the user can ask for more talking with the "what now" button, the Back Seat Driver should provide a "shut up" button (or other means to the same effect). The Back Seat Driver could also learn the effectiveness of its directions simply by watching the driver's performance—in particular, her errors. In this way, it can learn which cues are most effective.

Another opportunity for learning the driver's style is during the acquisition of speech recognition templates

(for user-dependent speech recognition for driver input means, described below). The new user should play the role of a "back seat driver" and give instructions, while in a car, for some route. The instructions must be given while driving either a real car or a close simulation because the form of static driving instructions is much different from real time instructions. Given some a priori knowledge about the ways that a route can be described, it is not impossible that the system could understand the instructions, and infer style from it. A difficulty here is that if the driver knows the route well, many things will seem obvious to her that would not be obvious to another person.

If the Back Seat Driver knows what the driver knows about the city, it can give better directions. A user who knows about a city no longer need instructions, she needs information about structure. The object description system preferably provides novice users a process description which emphasizes casual connections, and experts structural descriptions. Experts do not need the casual information, they can derive it for themselves.

The attributes of the user-model preferably include:

route-preference—does the driver want the fastest, shortest, or simplest route?

reassurance-period—how often should the program speak to the driver?

use-names—should the program tell the driver the names of passing streets?

congratulate-after-act—should the program make an explicity acknowledgment of correctness to the driver after each act?

obvious-to-cross-major—can the program assume that the driver will continue straight across a major intersection without being told explicitly to do so?

scoflaw—does the driver want to be warned when she is speeding?

daredevil—does the driver want warnings when driving dangerously fast?

distance-lowpass—does the driver want to be told the distance to the next action (in yards or miles, as appropriate). Most drivers do not understand distances in tenths of miles, so by default the program mentions only those distances that exceed one half mile.

The functions of the user-model preferably include:

obvious-next-segment—given a current position, is there a unique segment such that it is almost certain the driver will go there, without being told to do so?

at-major-intersection—is the current intersection one that the driver would call "major"?

extrapolate-path—try to predict the path the driver will follow in the next N seconds, assuming she does only what is obvious.

maximum-safe-speed—calculate the maximum speed at which the driver can get through an intersection. This calculation is based on finding the segment with the greatest radius of turn, and then calculating the largest speed the vehicle could have while making that turn without undergoing unacceptable sideways acceleration.

For the Back Seat Driver to decide what to say and when to say it, it preferably has a model of the vehicle performance. It must know, for example, how slowly the car should be going in order to safely make a turn. A suitably instrumented car could also measure the coefficient of friction by comparing the applied braking force and the resulting deceleration. This would allow it to adjust the time factors used in deciding when to speak.

The Back Seat Driver should understand the driver's plans and goals. When a driver enters a destination address, she is telling the system that she has the goal of getting to that address. The Back Seat Driver might guess at higher level plans from knowledge about the destination, and take actions to assist the driver with those plans. To do this, it must know what kind of thing is at the destination address. For instance, if the address provided is that of a store, the Back Seat Driver can guess that the driver is going there to purchase something, or at least to do business there. It could check the hours that the store is open.

The Back Seat Driver should help drivers to understand the route it gives. This would make the system more pleasant to use. It would also make it easier to follow routes because a driver who understands the route and the city will use that knowledge to help interpret the commands Back Seat Driver gives. A route should fit into a larger model of the city. This means that the Back Seat Driver itself must have a model of the city and should speak of the route in terms that relate it to the city. There are several opportunities to do this. At the beginning of the route, the driver might hear an overview of the route, naming the major paths followed and neighborhoods crossed. During the route, locations could be described not just as street address but in larger units of neighborhoods and districts. Orienting information can be included in instructions, or it might come between instructions, as a passing comment.

There are some additional services that the Back Seat Driver could easily provide. It should be able to give the location of a place without giving directions, it should be able to give the directions all at once, and it should be able to give directions between any two places. A driver might want to use these to tell someone else how to get to where they are.

The Back Seat Driver should be able to communicate with the outside world if the outside world is equipped to talk to it. For instance, after determining that a given parking garage is the closest or most convenient to the current destination, the Back Seat Driver could automatically phone or radio the garage and reserve a space.

The Back Seat Driver should be running on a computer embedded in the car, so that it can get more and better information about the state of the car and driver. For instance, when the next instruction is a turn, the Back Seat Driver should notice whether and when the driver turns on the turn signals. If the driver applies them too soon, it is possible (but not certain) that the driver has underestimated the distance to the turn; if applied at the "right time" then the system can take that the action has been understood; if never applied, then the driver has either misunderstood, or is driving hazardously.

The Back Seat Driver should also be integrated into the car's audio system, rather than having separate systems for voice and music. Furthermore, it should pay attention to what the driver is listening to. If the driver is listening to the radio, or playing a CD (or using a cellular telephone) the program should try to speak less often, on the grounds that the driver has implicitly indicated a preference for what to listen to. The program should suppress reminders and historical notes altogether. When it must speak, it should borrow the audio channel rather than trying to speak over it. The Back Seat Driver should also be aware of the driver's use of other controls in the car. It should defer speech

while the driver is adjusting the heat or the mirrors. for example. and suppress speaking altogether if the car makes sudden extreme changes in velocity. A driver trying to cope with an emergency situation does not need another distraction.

The discourse model preferred for the Back Seat Driver is a partial implementation of the discourse theory described by B. J. Grosz and C. L. Sidner ("Attention, intentions, and the structure of discourse" in *Computational Linguistics*, 12(3):175-204, 1986) and the theory of intonational meaning described by J. Hirschberg and J. Pierrehumbert ("The intonational structuring of discourse" in *Proceedings of the Association for Computational Linguistics*, 136-144, July 1986). Both of these articles are herein incorporated by reference. This model allows the program (or programmer) to create and manipulate discourse segments. The program specifies the contents of the discourse segment (both the syntactic form and the list of objects referenced) and the implementation of the model does the following: generates prosodic features to convey discourse structure; inserts discourse segment into intentional structure; and maintains attentional structure—adding new objects when mentioned and removing old objects when replaced. In addition it includes some useful low-level tools for natural language generation: search of attentional structure for occurence of co-referential objects; conjugation of verbs; generation of contracted forms; and, combination of sentences as "justification" sentences (e.g. "get in the right lane because you are going to take a right.") and sequential sentences ("Go three blocks. then turn left"). In order to use the discourse package the programmer must explicitly declare all semantic types used by the program, so in this case there are declarations for all objects which pertain to driving, such as street names, bridges, rotaries, stop lights and so on.

SPEECH GENERATOR

In the working prototypes of the Back Seat Driver, speech generation is performed by Dectalk, a commercial text-to-speech speech synthesizer, which is cabled to the main computing apparatus.

An alternative to synthesized speech is digitized speech, which is easier to understand than synthetic speech. Digitized speech, however, requires a great deal of storage space. There are more than 2000 different street names in Boston. Allowing another 500 words for the actual instructions, and assuming an average duration of 0.5 seconds for each word, coding this vocabulary at 64 kilobits per second would require 10 megabytes of speech storage. Given a Back Seat Driver that uses a CD-ROM for the map, the digitized speech could be stored on the disk as well. Coded speech would be more intelligible than synthesized speech, and less costly, but not as flexible. For, example, it would be impossible to read electronic mail using only stored vocabulary speech.

The generated speech is spoken to the driver through some kind of speaker system in the car. In a simple embodiment, the speaker system of the car radio is used.

DRIVER INPUT MEANS

Means for the driver to communicate with the backseat driver are required. For example, the driver must be able to enter destination addresses, request instructions or a repeat of instruction, and inform the Back Seat driver when an instruction cannot be carried out for some reason. In embodiments where the computing apparatus is installed in the automobile, a computer keyboard can be adapted to provide this communication means.

In one working prototype of the Back Seat Driver, the computing apparatus is not installed in the automobile, but is accessed through a cellular telephone. In this embodiment, the driver communicates with the Back Seat Driver by using the cellular telephone keypad. Address entry is achieved by first entering the digits, then a number sign, then spelling the street name using the letters on the telephone keypad. The letters "Q" and "Z" are on the "6" and "9" keys, respectively, and the space character is on "1", which is otherwise unused. These keys are sufficient to spell any street name in Boston. The spelling rules can be easily expanded to enter street names with other characters in them, for example, "4th Street".

In the implementation, spelling a street name requires only one button push for each letter, even though there are three letters on each key. This is because of the redundancy in street names, which are pronounceable words, not arbitrary strings. There are 37 pairs of street names in Boston with the same "spelling" in the reduced "alphabet". An example is "Flint" and "Eliot", both encoded as "35468". This is only one percent of the 2628 names of streets in Boston, so collisions are rare. This technique appears workable even for larger sets of names. When the entire word list of the Brown corpus is encoded, there are still only 1095 collisions in the 19,837 words (5.5%).

If a name collision occurs, the Back Seat Driver reads the list of possibilities, and asks the driver which one was meant. This is very rare. A more common problem is that street names are duplicated. When this happens, the Back Seat Driver asks the user a series of questions to reduce the list to a single choice. It tries to ask the fewest questions possible. It asks the user to choose from a list of street types, if that is sufficent to resolve the question, and otherwise from a list of the containing cities (or neighborhoods, if there are two instances within a single city). To select from a list, the Back Seat Driver reads the contents, asking the user to push a button when the desired choice is read.

The Back Seat Driver would be much easier to use if the driver could simply talk to it instead of using a keyboard or keypad. Speech recognition could be used for driver input means, however, address entry is a difficult task for speech recognition for the same reason it is hard for a human to understand machine speech—there are few constraints on a name. No speech recognizer available today can handle a 3000 word vocabulary with acceptable error rates. The car would also have to be stopped while the driver was speaking, because noise in moving cars for frequencies below 400 Hz can exceed 80 dB.

Back Seat Driver could also use speech recognition to replace the "What now?" and "What next?" buttons. This is a more tolerant application for speech recognition because there are fewer words to recognize.

SYSTEM PROCESSES

The Back Seat Driver carries out three separate tasks, each of which is executed by its own process. All processes share the same address space, so all variables and functions are accessible in every process, and no special mechanism for interprocedure call is required. Where necessary for synchronization, Back Seat Driver uses

queues or locks. All three processes are simple, infinite loops. The system processes are illustrated in FIG. 2.

The user process is the main process of the Back Seat Driver. It is this process which finds routes and gives instructions to the driver. The user process manages a list of goals. Each time around the loop, it selects a goal to work on, and does something to achieve the goal. if possible. The user process is connected to the speech generator, since that is how it talks to the driver.

The navigator process maintains an estimate of the current position and velocity of the car. It is connected to the position sensor by a serial line. Preferably, packets arrive from the position sensor several times a second. The navigator converts the data in the packets from the position sensor format to the format used by the Back Seat Driver.

There are two minor processes which assist the navigator process: The average speed process computes the running average speed of the vehicle over the last five seconds. It could be made part of the navigator process, but is distinct because it is more convenient that way. The position sensor monitor process keeps track of how often packets arrive. If packets do not arrive when scheduled, it should set a flag to indicate this to inform the driver if the position sensor ceases to work properly.

The control process is responsible for controlling the Back Seat Driver as a whole. The control process is connected to driver input means for entering, for example. the destination and requesting additional instructions while driving (e.g. the "What now"?, "What next?" and "I can't do it" features.) Other functions of the control process are useful in a research prototype, but should not be required in a commercial embodiment of the Back Seat Driver. One such function is debugging.

The user process is a goal-driven perpetual loop which seeks to use the resources available to it to satisfy as many goals as possible as quickly as possible, devoting resources first to those goals which are of greatest importance. There are two aspects to this process, goal structures (which names goals) and goal-functions (which tell how to accomplish them). A goal is just a name, a priority (a number). and a set of slots (parameters). Thus for instance a typical goal would be (GET-TO-PLACE<140 Elm Street>). where the goal has one slot. namely the destination. A goal-function is a function which is possibly able to achieve a goal. When a new type of goal is defined, the programmer also tells the system which goal functions can possibly meet it, and later, when the system tries to accomplish a goal it selects from this list.

The goal loop is a three step process. 1) Check to see whether there are any newly added goals. The driver can add a goal by hitting a key, and the system can also add goals. 2) Find the most important goal to work on. 3) Work on that goal. In general, systems should use resources in the most efficient manner possible. For the Back Seat Driver, the only resource is speaking time. The only way the Back Seat Driver can accomplish any of its goals is by speaking. Speech is a resource because the program can only say one thing at a time, and speaking takes a finite time. It is also important to note that spoken utterance has a useful effect only if completely spoken, so it is not helpful to begin to speak if there is not time to complete the speech.

The protocol for a goal function preferably includes the following:

progressable?—Is the goal able to accomplish anything at this time?

resource-used—If it runs now, what resources will it want to use?

maximum-time-of-resource—If it runs now, how long (in seconds) will it need each resource?

minimum-time-to-resource—The minimum time that it can estimate until it may again need this resource, and the priority of its use at that time.

In the working prototypes of the Back Seat Driver, the list of all goals is stored in the global variable *goals*. The goal loop and goal structures are defined in the file goals.lisp. The various goals and goal functions of the Back Seat Driver are defined in the files main.lisp, route-goals.lisp, and get-to-place.lisp. All goals which use speech are built from the speech-goal object defined in speech-goal.lisp. The speech resource itself is defined in speech-resource.lisp.

The goal or function which gets a user to a destination is called GET-TO-PLACE. An explanation of this goal will illustrate the goal mechanism in more detail, as well as illustrate how this most important function of Back Seat Driver is implemented. The goal GET-TO-PLACE, has two slots, destination which is the location the user wants to get to, and route which is the route the Back Seat Driver intends to use to get there.

The driver adds the goal to the system goal list by striking a key. When the goal is first created, the destination is not known (the destination slot is empty), so the goal function for GET-TO-PLACE creates a sub-goal, GET-DESTINATION, and adds it to the goal list. Now there are two goals on the goal list, GET-TO-PLACE and GET-DESTINATION, but only the second is progressable, because when a goal has a sub-goal, it is not allowed to run until the sub-goal finishes. Therefore, the only progressable goal is GET-DESTINATION, which attempts to get a destination by asking the user to enter an address. If the user fails to do so, the subgoal fails, which in turn causes GET-TO-PLACE to fail, and the Back Seat Driver says "Travel cancelled". Otherwise, it writes the destination into the destination slot of the GET-TO-PLACE goal. Now that the sub-goal is complete, GET-TO-PLACE can once again make progress. This time it finds that the route slot is empty, and again calls for the sub-goal GET-ROUTE, which calculates a route. When this is complete a third subgoal is invoked, namely FOLLOW-ROUTE.

The goal function for FOLLOW-ROUTE gets the driver to the destination by speaking instructions. If something goes wrong (for example if the driver makes a mistake) then the subgoal fails. But this does not make GET-TO-PLACE give up. Instead, it erases the route slot, and simply finds a new route, and then tries FOLLOW-ROUTE again. This continues, no matter how many times things go astray, until either FOLLOW-ROUTE succeeds, or the driver cancels the trip.

The goal FIND-SERVICE is similar to GET-TO-PLACE except the driver selects a kind of service (for example, a gas station), and then the Back Seat Driver finds the closest provider of that service, and then finds a route to it. Following that route is done by FOLLOW-ROUTE in the same way as for GET-TO-PLACE.

The FOLLOW-ROUTE goal function gets the user to her destination by giving spoken instructions. There are several reasons it might speak:

at the beginning, to alert the driver

to give an instruction in advance, so the driver will be ready
to give an instruction when it is time to do it
to confirm that the driver has correctly carried out an instruction
to inform the driver of her arrival at the destination
to reassure the driver that she is still on route
to inform the driver of a mistake
to warn the driver that she is driving so fast that the program cannot keep up.

FOLLOW-ROUTE decides the next reason for speaking by first trying to locate the current position on the path. If the position is not on the path (more precisely, if the current segment does not occur anywhere on the path) then the driver has left the path (or the position sensor has made an error). Otherwise, FOLLOW-ROUTE determines what instruction must be next executed by calling the function next-driver-instruction.

The goal function protocol requires that FOLLOW-ROUTE support the goal function minimum-time-to-resource, which estimates the minimum time until FOLLOW-ROUTE will next speak. This time depends upon the reason for the next speaking. FOLLOW-ROUTE speaks immediately when beginning, confirming, warning, or finishing the route. When the driver is off the route, FOLLOW-ROUTE waits a few seconds before speaking, just in case the driver's departure from the route is actually a temporary error by the position sensor.

Given that the driver is on the path, FOLLOW-ROUTE determines when to speak by calculating the position where it must begin speaking the instruction text, then estimating the time required to reach that position at the driver's current speed. As the driver's speed changes, so will this estimated time. The position to begin speaking is calculated by first finding the position where the instruction is executed, then moving back a distance to allow the Back Seat Driver time to speak the text and the driver to react to it.

The Back Seat Driver can also give instructions in advance, if desired. It does this in much the same way, except that it adds an additional number of seconds (normally thirty) to the time estimate, and so begins to speak much sooner. When it gives instructions in advance the instruction text is longer because the program has more time to speak.

When the driver leaves the route FOLLOW-ROUTE starts a timer. If the driver has not returned to the route by the time the timer goes off (at present, two seconds) then FOLLOW-ROUTE checks for a possible mistake. In describing the mistake, it attempts to characterize what the driver actually did as well as what the program intended the driver to do. It is able to do this because in the main loop it stored the last position that the driver was on when last on the route.

Goals may interrupt lower priority goals by requesting the speech resource to interrupt the lower priority goal. Interruption stops the speech synthesizer immediately. The interrupted goal is informed of the interruption, and can react as it chooses. There is no way for the goal to know whether any of its words were actually spoken, so it has to start all over. Most goals attempt to run again as soon as possible. The assumption is that the interruption occurred because the user started some higher priority goal after learning how to do so through the help command.

The system treats "repeat the last statement" as a goal, rather than as a special purpose function, except that the importance of this goal is set to the value of the last goal spoken (the goal whose utterance is being repeated). This guarantees that if some more important goal desires to speak, it will be able to. A repetition of an utterance is no more important than it was originally.

Goals can be temporary or presistent. Temporary goals can be satisified, but persistent goals never can be. All system initiated goals are persistent. The system goals include warning the driver of dangers ahead (WARN-DRIVER) and informing the user of new electronic mail or other messages (if the computer apparatus of the Back Seat Driver is connected to the outside world). These goals can never be satisified. The driver's safety should always be preserved and mail or messages can arrive at any time.

CELLULAR PHONE EMBODIMENT

The Back Seat Driver is preferably an in-car navigation system, but in some embodiments, it may be desirable to not have the entire computing apparatus installed in the car. This is the case if the computing apparatus is too large or if a number of cars are to share a single computing apparatus.

For such embodiments, two cellular phones installed in the car can be used to transmit data from the car to the computing apparatus, and to receive voice from the speech generator in the computing apparatus. In this embodiment, data from the position sensor installed in the automobile is sent through a cellular phone in the car equipped with a modem to a phone connected to the computing apparatus via a modem. The voice generating apparatus of the computing apparatus sends speech over another phone to a second cellular phone installed in the automobile.

This embodiment has been implemented in a working prototype, using a large workstation computer (a Symbolics Lisp Machine). In this implementation, a position sensor installed in the car estimates vehicle position, heading, and velocity, and sends a data packet, once per second, through a modem to the workstation. The workstation sends characters to a Dectalk speech synthesizer, which in turn sends voice over a second phone to the driver.

Nearly everyone who has used a cellular phone knows how noisy they are. Cross talk is common and noise bursts and signal loss make it hard to hear. A sufficiently bad noise burst can even cause the cellular system to terminate the call. The problems for data transmission are even worse. By its very nature, cellular radio transmission is subject to multi-path interference, which causes periodic fades as the antenna moves in and out of anti-nodes. In addition to this fading, there is a complete loss of audio signal for as long as 0.9 seconds when the phone switches from one cell site to another (hand off).

An attempt to use an ordinary (land-line) modem from the car was unsuccessful. In the prototype, a Worldlink 1200 from Touchbase Systems was used in the car, with a Morrison and Dempsey AB1 data adapter, and an NEC P9100 phone, boosted to 3 watts. At the base station, both a Practical Peripherals 2400 and a Hayes Smartmodel 1200 were used. Even at 300 baud the connection was too noisy to use. Worse, connections seldom lasted more than five minutes. In all cases, the "loss of carrier" register (S10) was set to its maximum value, 20 seconds. Loss of carrier signal alone

cannot explain why the connections dropped. The modems were capable of tolerating a complete loss of audio for up to twenty seconds.

Better results were found using an error correcting modem (The "Bridge") made by the Spectrum Cellular Corporation. This modem uses a proprietary protocol (SPCL) for error correction. The Spectrum product virtually eliminated noise, at the price of a lower data transmission rate. According to the protocol, the transmitting modem groups characters into packets that include error correction bytes. If only a few errors occur, the receiving modem repairs the data and acknowledge receipt. If there are many errors, the packet is retransmitted. If the sending modem has to retransmit too often it makes the packets smaller, on the assumption that a smaller packet has a better chance of success. This is less efficient, since packets have a fixed overhead, the percent of the channel used by data decreases. When conditions improve the modem increases packet size again. In theory, the modem can transmit at 120 characters per second, but tests made by recording the time required to receive the three characters of an odometer sequence demonstrated that the average value is closer to 30 characters per second. This sequence is transmitted once per second. The mean for durations for the three character sequences is 94 milliseconds, which is 31 milliseconds per character, or 32 characters per second.

Even with the cellular modem, calls are sometimes dropped. The call durations are usually long enough for a successful trip with the Back Seat Driver. Voice calls are dropped at about the same rate as data calls.

The protocol used by the Spectrum modem acknowledges all data transmitted. If the acknowledgment is not received, it retransmits the data until acknowledged. Under adverse conditions, this can result in an arbitrarily long delay. This is a problem when real-time data is transmitted. Observation of the Back Seat Driver shows that sometimes the system will "freeze" for from one to ten seconds. During this time, the car of course continues to move. If these freezes occur near decision points, the driver may go past the intersection without being told what to do. At 20 miles per hours a car travels nearly 45 meters in five seconds. The navigation system in the car sends a packet once every second. Most packets arrive within a second, but a few are delayed, some by up to ten seconds. (These delays may also arise from delays at the workstation. Lisp Machines are not noted for real-time response.)

It would be better to have a protocol which guarantees to deliver data intact and free of errors, if it delivers it at all, but does not guarantee to deliver the data. Real time data is only valuable in real time, and time spent retransmitting old data is taken away from ever, more valuable data. Such a protocol modification is feasible for the Spectrum product.

What is claimed is:

1. An automobile navigation system which produces spoken instructions to direct a driver of an automobile to a destination in real time comprising:

computing apparatus for running and coordinating system processes,

driver input means functionally connected to said computing apparatus for entering data into said computing apparatus, said data including a desired destination,

a map database functionally connected to said computing apparatus which distinguishes between physical and legal connectivity,

position sensing apparatus installed in the automobile and functionally connected to said computing apparatus for providing said computing apparatus data for determining the automobile's current position,

a location system functionally connected to said computing apparatus for accepting data from said position sensing apparatus, for consulting said map database, and for determining the automobile's current position relative to the map database,

a route-finder functionally connected to said computing apparatus, for accepting the desired destination from said driver input means and the current position from said location system, for consulting said map database, and for computing a route to the destination,

a discourse generator functionally connected to said computing apparatus for accepting the current position from said location system and the route from said route finder, for consulting said map database, and for composing discourse including instructions and other messages for directing the driver to the destination from the current position,

a speech generator functionally connected to said discourse generator for generating speech from said discourse provided by said discourse generator, and

voice apparatus functionally connected to said speech generator for communicating said speech provided by said speech generator to said driver.

2. The automobile navigation system of claim 1 wherein said map database comprises a set of straight line segments and a set of nodes, each endpoint of each segment being a pointer to a node representing the coordinates of the endpoint and the set of other segments which are physically and legally connected to that endpoint.

3. The automobile navigation system of claim 1 wherein said map database is based on DIME files of the United States Census extended to represent physical and legal connectivity.

4. The automobile navigation system of claim 3 wherein said DIME file is further extended to distinguish bridges, underpasses, tunnels, rotaries, and access ramps from other street types.

5. The automobile navigation system of claim 1 wherein said map database is based on TIGER files of the United States Census and United States Geological Survey extended to represent physical and legal connectivity.

6. The automobile navigation system of claim 5 wherein said TIGER file is further extended to distinguish bridges, underpasses, tunnels, rotaries, and access ramps, from other street types.

7. The automobile navigation system of claim 1 wherein said map database comprises a three-dimensional representation of street topology.

8. The automobile navigation system of claim 1 wherein said map database includes measures of street quality.

9. The automobile navigation system of claim 1 wherein said map database distinguishes divided streets.

10. The automobile navigation system of claim 1 wherein said map database includes landmarks such as signs, traffic lights, stop signs and buildings.

11. The automobile navigation system of claim 1 wherein said map database includes lane information.

12. The automobile navigation system of claim 1 wherein said map database includes speed limits.

13. The automobile navigation system of claim 1 wherein said map database includes expected rate of travel.

14. The automobile navigation system of claim 1 wherein said map database includes time-dependent legal connectivity.

15. The automobile navigation system of claim 1 wherein said map database includes turn difficulty.

16. The automobile navigation system of claim 1 wherein said map database includes vehicle street, lane, and height restrictions.

17. The automobile navigation system of claim 1 wherein said map database includes traffic light cycles.

18. The automobile navigation system of claim 1 wherein said map database distinguishes where right turn on red is allowed.

19. The automobile navigation system of claim 1 wherein said map database includes a database of service locations.

20. The automobile navigation system of claim 1 wherein said map database includes a listing of famous places by name.

21. The automobile navigation system of claim 1 further comprising means for updating said map database.

22. The automobile navigation system of claim 1 further comprising means for updating said map database by radio broadcast.

23. The automobile navigation system of claim 1 wherein the map has minimum accuracy of 10 meters.

24. The automobile navigation system of claim 1 wherein said route finder is based on a best-first search algorithm.

25. The automobile navigation system of claim 1 wherein said route finder is based on an A* algorithm.

26. The automobile navigation system of claim 1 wherein said route finder is based on an A* algorithm modified to find a route in less time.

27. The automobile navigation system of claim 1 wherein said route finder is adapted to find a best route according to any one of three cost metrics: distance, speed, simplicity.

28. The automobile navigation system of claim 1 wherein said route finder is adapted to calculate a new route if the driver or vehicle navigation system makes an error or if the route is unnavigable due to unforeseen circumstances, wherein said new route does not simply backtrack to the point of the error if a better route from the current location exists.

29. The automobile navigation system of claim 1 wherein said route finder is adapted to calculate a new route while the automobile is in motion, wherein said new route will begin from the location of the automobile at the time the calculation of the new route is completed.

30. The automobile navigation system of claim 29 wherein an estimated time to find a new route is multiplied by the velocity of the automobile to calculate the position from which the new route should start.

31. The automobile navigation system of claim 30 wherein said estimated time to find a new route is calculated by multiplying the distance between the starting and ending points of the new route by a constant.

32. The automobile navigation system of claim 1 wherein said location system is a position-keeping (dead-reckoning) system.

33. The automobile navigation system of claim 1 wherein said location system is a hybrid of position-keeping and position-finding systems.

34. The automobile navigation system of claim 1 wherein said location system employs map matching.

35. The automobile navigation system of claim 1 wherein said position sensing apparatus comprises displacement and direction sensors installed in the automobile.

36. The automobile navigation system of claim 1 wherein said position sensing apparatus measures displacement with an odometer.

37. The automobile navigation system of claim 1 wherein said position sensing apparatus measures direction with a magnetic compass.

38. The automobile navigation system of claim 1 wherein said position sensing apparatus measures direction by monitoring the turning of the steering wheel.

39. The automobile navigation system of claim 1 wherein said position sensing apparatus measures direction with a differential odometer.

40. The automobile navigation system of claim 1 wherein said position sensing apparatus measures direction with a gyroscope.

41. The automobile navigation system of claim 1 wherein said discourse generator is based on an object-oriented programming methodology.

42. The automobile navigation system of claim 1 wherein each intersection in a route is classified into one type in a taxonomy of intersection types, and the disclosure generated in relation to each said intersection depends on its type.

43. The automobile navigation system of claim 42 wherein said taxonomy of intersection types includes continue, forced-turn, U-turn, enter, exit, onto-rotary, stay-on-rotary, exit-rotary, fork, turn, and stop.

44. The automobile navigation system of claim 42 wherein said discourse generated further depends on a description function for each intersection type which generates a description given the length and tense of the desired description and the position along the route from which an instruction is to be given.

45. The automobile navigation system of claim 1 wherein said discourse generated comprises a long description of an act given substantially before the act is to be performed and a short description given at the time the act is to be performed.

46. The automobile navigation system of claim 45 wherein said long descriptions includes cues.

47. The automobile navigation system of claim 46 wherein said cue is a landmark.

48. The automobile navigation system of claim 1 wherein said driver input means includes means for said driver to demand immediate instructions, or clarification or repetition of instructions already provided.

49. The automobile navigation system of claim 1 wherein said driver input means includes means for said driver to indicate to said automobile navigation system that a given instruction provided by said system is impossible to complete for some reason and that a new route must be calculated.

50. The automobile navigation system of claim 1 wherein said driver input means comprises a voice recognition system to allow at least some driver input to be spoken.

51. The automobile navigation system of claim 1 wherein said automobile navigation system records a history of the route and the discourse already generated and uses this knowledge to generate cues for future discourse and make future discourse more understandable.

52. The automobile navigation system of claim 1 wherein said automobile navigation system warns drivers of dangers inferred from knowledge of the road network.

53. The automobile navigation system of claim 1 wherein said automobile navigation system informs a driver if an error has been made as detected by the location system.

54. The automobile navigation system of claim 1 wherein said discourse generator is responsive to a user-model stored in said computing apparatus to customize discourse to the requirements and preferences of said driver.

55. The automobile navigation system of claim 1 wherein said speech generator is a speech synthesizer.

56. The automobile navigation system of claim 1 wherein said speech generator uses digitized speech.

57. The automobile navigation system of claim 1 wherein said computing apparatus is not installed in the automobile, and said automobile navigation system further comprises means for communication between said computing apparatus and the automobile navigation system components installed in the automobile.

58. The automobile navigation system of claim 57 wherein said means for communication is two cellular phones in said automobile, one of which is connected to a modem, and two phones connected to said computing apparatus, one of which is connected to a modem, whereby one data channel and one voice channel between said automobile and said computing apparatus is created.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,177,685 Page 1 of 2

DATED : January 5, 1993

INVENTOR(S) : James R. Davis, et al.

It is certified that error appears in the above-indentified patent and that said Letters Patent is hereby corrected as shown below:

Column 1, line 18: after "all" please insert "three";

Column 7, line 50: delete "street" and insert therefor -- streets --;

Column 11, line 11: after "algorithm" please insert ", ";

Column 11, line 66: after "compass" and before "A" please insert ": ";

Column 12, line 4: after "wheel" and before "The" please insert ": ";

Column 12, line 6: after "odometer" please insert ": ";

Column 12, line 14: after "gyroscope" and before "Gyroscope" please insert ": ";

Column 16, line 36: delete "to also" and insert therefor -- also to --;

Column 17, line 18: delete "its" and insert therefor --it is --.

Column 17, line 18: delete "that";

Column 17, line 20: delete "if" and insert therefor -- is --;

Column 17, line 18, delete "it".

UNITED STATES PATENT AND TRADEMARK OFFICE

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DATED : January 5, 1993

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Page 2 of 2

It is certified that error appears in the above-indentified patent and that said Letters Patent is hereby corrected as shown below:

Column 18, line 61: delete "work" and insert therefor -- word --;

Column 21, line 16: delete "need" and insert therefor -- needs --;

Column 21, line 19: delete "casual" and insert therefor -- causal --;

Column 21, line 21: delete "casual" and insert therefor -- causal --;

Column 28, line 8: delete "presistent" and insert therefor -- persistent --;

Column 29, line 13: delete "knowledge" and insert therefor -- knowledges --;

Column 32, line 33-34: delete "disclosure" and insert therefor -- discourse --; and

Column 32, line 52: delete "includes" and insert therefor -- include --.

Signed and Sealed this

Fifteenth Day of March, 1994

Attest:

Bruce Lehman

BRUCE LEHMAN

Attesting Officer

Commissioner of Patents and Trademarks

MIT 00456

EXHIBIT 2

Direction Assistance

James Raymond Davis
and
Thomas Frank Trobaugh

December 1987

Speech Research Group Technical Memo 1
The Media Laboratory
Massachusetts Institute of Technology

Abstract

Direction Assistance is an interactive program that provides spoken directions for automobile travel within the Boston area. The program has a telephone interface which uses touch tone keypad input and synthetic speech output. Routes are both short and easily followed. The directions are given in fluent English. The program has successfully directed newcomers through Boston.

This paper tells how we built Direction Assistance, with emphasis on how the available databases are and are not useful for this application. It also talks about automatic generation of route descriptions, and compares our work to that of others.

1 Introduction

1.1 Overview

Direction Assistance consists of about 11,000 lines of CommonLisp code, runs on a Symbolics Lisp Machine, and uses a Digital Equipment Corporation DecTalk synthesizer. It was written mostly during the summer of 1985 at the Thinking Machines Corporation of Cambridge, Mass. Since then, it has undergone periodic rewrites. It is running at the Media Lab, and is also installed at the Computer Museum in Boston and as part of the Age of Intelligent Machines exhibit traveling across the United States.

Direction Assistance consists of five modules. The **Location Finder** queries the user to obtain the origin and destination of the route. A location may be specified as a street address or as a telephone number. The **Route Finder** finds a simple, short route between the two points. The **Describer** generates high quality English text describing the route. The **Narrator** recites the route to the user. In addition, there is a **graphical interface** for maintenance.

These modules share a set of databases. The most important is the street map, which covers an eleven square mile area of Boston centered on the Charles River. A second database is an inverted phone directory, which provides a street address for a phone number.

In this paper, we discuss the databases, the Route Finder, and the Describer. The Location Finder and Narrator are described in [2].

It would be inappropriate to continue without mentioning the pioneering work of Jane Elliot and Mike Lesk[5,4]. Our work differs from theirs in several ways. Our interface uses synthetic speech and pushbutton telephones rather than a graphics terminal. We are much more concerned with generating fluent English text than they. On the other hand, we are not much concerned with route finding algorithms. Finally, Elliot and Lesk used a Yellow Pages database in addition to the white pages and street map. We will not clutter this paper with citations to Elliot and Lesk on every point where they have made contributions. They are to be assumed.

We next discuss the underlying databases, and then the modules which use them. The description of the databases will by necessity refer to features of the program in order to motivate the construction of the database.

2 Databases

2.1 Streets

Our street map began as a DIME (Dual Independent Map Encoding) file distributed by the United States Geological Survey[1]. A DIME file consists of a set of straight line segments, each with a name, a type, endpoints in longitude and latitude, and some additional information. Segment types include natural features (chiefly water boundaries), railroads, town and property lines as well as streets. The latter are also labeled with address numbers on both sides of the street at each endpoint; thus is is possible to estimate the coordinates for any street address by interpolation, assuming all lot sizes to be constant.

We began with an 11 square mile subset centered roughly on the Charles River. This includes portions of Boston (Charlestown, Allston, Back Bay, South End, North End), Brookline, and Cambridge (Cambridgeport and Harvard, Inman, Central and Kendall Squares). (See figure 1.) There are about 279 miles of streets in the map, which contains 6163 segments, of which 5506 correspond to streets. The total size is about 477 kilobytes.

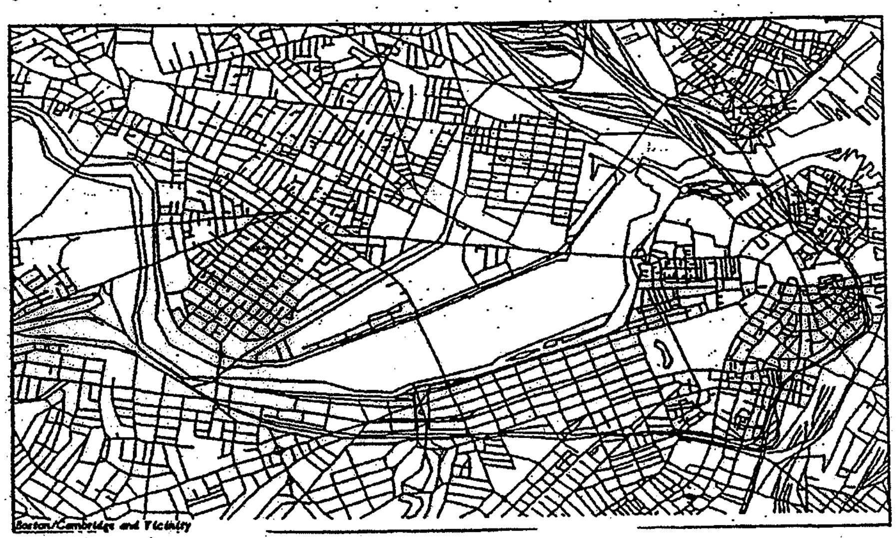

Figure 1: Street Database

The DIME file as supplied was far from suitable for our use. It contained many errors: streets were missing, mislabeled, or misconnected, and names were not spelled consistently. In some cases, more than one segment occupied the same place, and some segments were connected to themselves. We wrote a

EXHIBIT 3

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF MASSACHUSETTS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Plaintiff, v. HARMAN INTERNATIONAL INDUSTRIES, INCORPORATED, Defendant.	Civil Action No: 05-10990 DPW

REBUTTAL EXPERT REPORT OF BARBARA J. GROSZ, PH.D.

references contain sufficient detail to allow one of skill in the natural language processing field, let alone one of skill in the navigation art to build a discourse generating component comparable to that of the '685 patent.

5. There are ten columns of text in the '685 patent devoted to describing the "Discourse Generator" element of the Back Seat Driver. '685 patent, col. 13, l. 22 – col. 23, l. 37. In my opinion, the French Report fails to understand or otherwise acknowledge the importance of the discourse model and discourse generation to the inventions of the '685 patent. In particular, the French Report devotes less than 4 pages of the 59-page body of the report to the "Real-time spoken directions" aspect of the '685 patent. See French Report pp. 16-19. The French Report does not address discourse theory or discourse generation in detail anywhere in the report.

6. Additionally, the French Report appears to conflate "finding a route" with "describing a route," but these are separate concepts. To find a route is not the same as to describe a route. The French Report and the references I considered that discussed providing verbal instructions appeared to do so by tying the verbal instructions to the particular route-segments and almost always take the form of simple instructions. Producing a simple, brief description for each segment of the route does not constitute having a discourse generator for describing routes. For example, the simple instructions appear to be "canned" text generated from the route, and the instructions lack any discourse-linguistic structure. All of the cited references I considered focused on finding a route and solving the database and search problems involved. The speech capabilities are tacked on, not handled in a principled way, and appear to contain no discourse capabilities.

7. In particular, finding a route involves logically assembling a set of route segments from a starting point to a destination. In the French Report and cited references, each route segment is associated with a particular brief description of an act, and each brief description is associated, therefore, with the way the route was found. In contrast, Davis and Schmandt abstracted the way the route was found to teach how the route should be described by the generated English speech in a way that was understandable by the driver. More specifically, the '685 patent describes how to abstract a series of route segments and logically organize the description of route segments around intersections.

8. The '685 patent describes using object-oriented programming to organize route description data around decision points, typically intersections. This was a very important abstraction that enabled efficient discourse generation. Rather than presenting driving instructions to the driver simply as calculated by a route-finding algorithm, directions were presented to the driver in a way a human might think about giving directions. The French Report and other references I considered purport to discuss generation of routes, but neither the French Report or cited references teach about describing a route.

9. Organizing the driving directions around intersections also allowed multiple instructions to be given for a particular maneuver, including a long description and a brief description of driving acts. Moreover, organizing directions around intersections allowed the discourse generator to be designed and built more effectively and efficiently, such that a significant reduction in the amount of time to compute and produce the directions as output resulted. To the extent that the cited references or the French Report discuss turn instructions, the simple turn instructions are a by-product or accident of the planned route and do not represent discourse generated from a description function associated with the intersection.

10. Many of the references cited or addressed in the French Report appear to be written from a route-finding perspective without understanding the technical and practical difficulties of designing a system capable of generating real-time directions tailored to a driver and driving situation in a widely applicable way. More specifically, some of the references purport to describe systems that provide verbal directions to a driver based on the driver's planned route. In most cases, the verbal directions take the form of simple instructions to turn given at the time of the turn.

11. None of the references I considered describe in detail how the spoken instructions are generated. Simply presenting an example of directions provides no information about how to design a system capable of producing that linguistic behavior in a general manner as described in the '685 patent. Some references describe spoken instructions that are prerecorded and played back to a driver upon the driver's request. Such directions are obviously not produced by a discourse generator in real-time. Moreover, these references do not teach how to generate from a general discourse model map directions using a real-time discourse generator. Each of the references that describe voice output without describing how the voice output was generated require someone to create the natural language directions-generating system based only on the output. This is an incredibly challenging task and one that would require a great deal of creativity, inventiveness, and experimentation that would essentially duplicate solving the problem that Davis and Schmandt solved and described in the '685 patent. Thus, the '685 patent represents an achievement not only in natural language processing and discourse theory, but also in the field of in-vehicle guided navigation.

12. In my opinion, James Davis' Ph.D thesis and the '685 patent are the first papers that describe in detail mechanisms for discourse-generation algorithms that produce intelligent

spoken directions to direct a driver to a destination. Davis' work was the first to create and describe an operable system that could be built or used to provide such spoken directions. I am unaware of any automobile navigation system that incorporated the necessary discourse and speech generating technology to provide real-time spoken instructions in a system with components or equipment that was able to fit into a passenger automobile. Davis' work represented a breakthrough in the application of discourse theory and natural language processing techniques to a real-world system that could operate effectively in taking both driving and discourse contexts into accounts.

IV. Background of Discourse Generation and Natural Language Processing

13. The '685 patent relates to an automobile navigation system which provides spoken instructions in real time to direct a driver of an automobile to a destination. The spoken instructions are composed by a discourse generator according to a discourse model and provided to the driver in real time as they are needed. I plan to testify about the background of discourse models, discourse generation, real-time driving instructions according to a discourse model, the prior state of the art, and the inventions described in the '685 patent.

14. My initial expert report set forth a discussion of the general understanding of discourse theories and natural language processing, and I incorporate that general understanding in this report. This general understanding would apply both today and in August of 1990 (the time of filing of the '685 patent).

15. In the 1986-1988 time frame, James R. Davis along with Thomas Trobaugh worked on a computer program called "Direction Assistance." See Defendant's Deposition Exhibits 73 & 74. Direction Assistance included a map database, a route-finding program, and

EXHIBIT 4

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF MASSACHUSETTS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Plaintiff, v. HARMAN INTERNATIONAL INDUSTRIES, INCORPORATED, Defendant.	Civil Action No: 05-10990 DPW

<u>REBUTTAL EXPERT REPORT OF LYNN A. STREETER, PH.D.</u>

phone network could do for automobile navigation, but it was understood that this technology was still in the future.

55. Moreover, the statements in the concluding paragraph of *Streeter* were meant to presage further research in the area of navigational systems. HAR000205. At the time of *Streeter*, computers did not process data sufficiently fast to enable route-planning, positioning with map-matching, database access, and discourse and/or speech generation to occur in the vehicle or even fast enough to enable a vehicle to rely on off-board equipment. Jim Davis' work over the course of 5 years subsequent to *Streeter* is illustrative of the effort and ingenuity that was required in order to design and implement an operational navigation system that could provide real-time spoken driving instructions according to a discourse model. In my opinion, Chris Schmandt and Jim Davis' work and the work embodied in the '685 patent was the first to implement an operational real-time navigation system in an automobile environment that provided real-time spoken instructions that were similar to those a human would give.

56. *Streeter* discusses a controlled experiment that yielded a particular result, focused on a particular aspect of human understanding. *Streeter* did not build, use, describe or discuss a navigation system that operated in real-time. The demands on the driver in the *Streeter* experiment and the format of the driving instructions precluded the experimental system used from being automatable. The result of the *Streeter* experiment illuminated a counter-intuitive result that warranted additional research in the area of direction following and human reactions.

57. I understand that Harman is alleging that the '685 patent is unenforceable on the grounds of inequitable conduct because *Streeter* was not cited during prosecution of the '685 patent. In my opinion, *Streeter* is cumulative of the references actually cited during prosecution

EXHIBIT 5
(filed under seal)

EXHIBIT 6

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Expert Report of Robert French

the IEEE Vehicular Technology Conference in Detroit in 1971, the Detroit News referred to my system as "An Electronic Backseat Driver." Starting in 1972 I devoted much of my time to promoting the technology that I had developed, researching alternative technologies, and studying the history of vehicle navigation. Following Etak's agreement to license under my patent (United States Patent No. 3,845,289 ("the French patent") (HAR 245975 - 246013)) in the mid-1980s, I used my accumulation of knowledge in the field to offer consulting services to others interested in vehicle navigation and route guidance. In 1985, Rand McNally became my first client in this new endeavor. Over the next few years I established consulting relationships with world class clients throughout North America, Europe and Japan, and became very familiar with most of the development work that was underway on vehicle navigation and route guidance.

I believe that this background, along with the extensive archives I've accumulated along the way, make me uniquely qualified to offer expert consultation in this case. These qualifications are summarized in my curriculum vitae as Exhibit A to my report.

5. The Level of Ordinary Skill in the Art

Generally, a person of ordinary skill in the art of the subject matter claimed in the '685 patent at the time of the claimed invention[1] would have possessed the equivalent of

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[1] I understand that MIT says that certain subject matters claimed in the '685 patent were conceived by MIT in 1988. I also understand that the "prior art" to the '685 patent includes printed publications published more than one year before the filing of the patent application for the '685 patent, and that such art is relevant to the validity of the patent. My opinions as to the invalidity of the '685 patent, which are based on the prior art, are not impacted by the exact timing of MIT's conception. In any event, the analysis and opinions would be the same under either the 1988 or 1989 time frame.

Regarding the 1989 time frame, I first learned of the MIT work around January of that year when, as Technical Program Vice Chairman for the IEEE VNIS'89 conference held in Toronto, September 11-13,1989, I reviewed an abstract entitled "The Back Seat Driver: Real Time Spoken Driving Instructions," that Davis and Schmandt submitted for that conference. VNIS'89 ("Vehicle Navigation and Information Systems") was the first major technical conference to be devoted exclusively to topics relating to vehicle navigation and route guidance. Many of the other papers presented at VNIS'89 reported on, or alluded to, much of the prior art cited in this report.

EXHIBIT 7

US 20060031009A1

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Brulle-Drews

(54) NAVIGATION SYSTEM WITH ACOUSTIC ROUTE INFORMATION

(76) Inventor: Christian Brulle-Drews, Hamburg (DE)

Correspondence Address:
INDIANAPOLIS OFFICE 27879
BRINKS HOFER GILSON & LIONE
ONE INDIANA SQUARE, SUITE 1600
INDIANAPOLIS, IN 46204-2033 (US)

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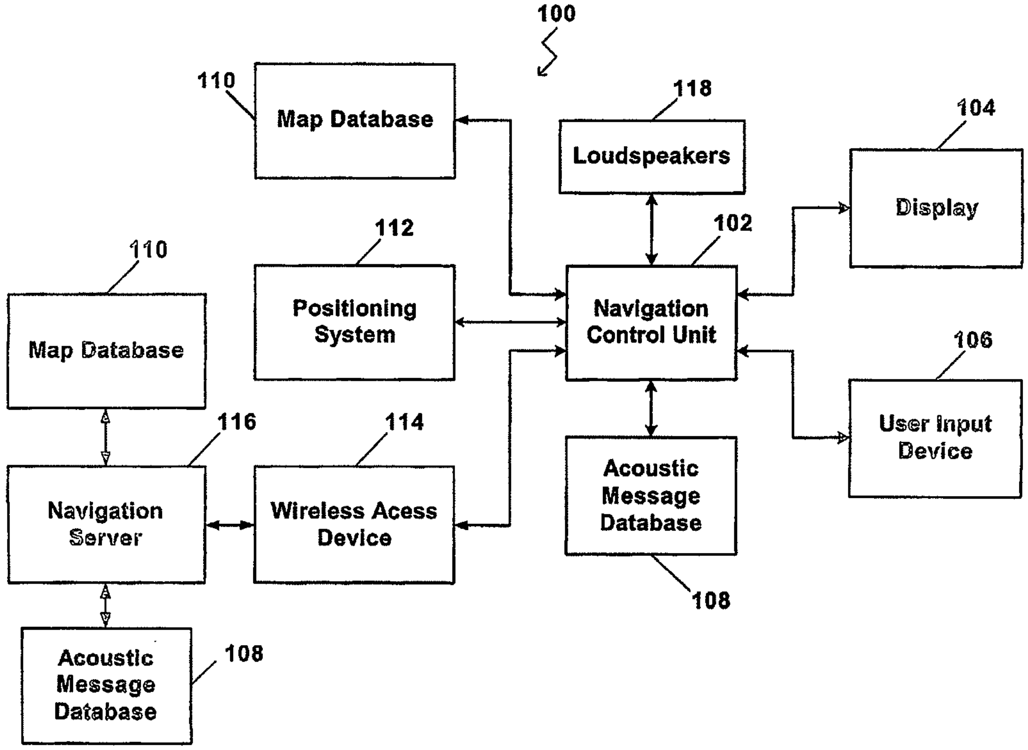
(57) ABSTRACT

A navigation system (100) capable of providing acoustic route information summarizing a route to a predetermined destination. The navigation system (100) includes a route calculation module (110) that is capable of calculating a route to a trip destination. A route overview module (104) may also be included for creating a route overview list that is based on the route. An acoustic message module (108) may be used to generate at least one acoustic route overview message as a function of the route overview list associated with the route.



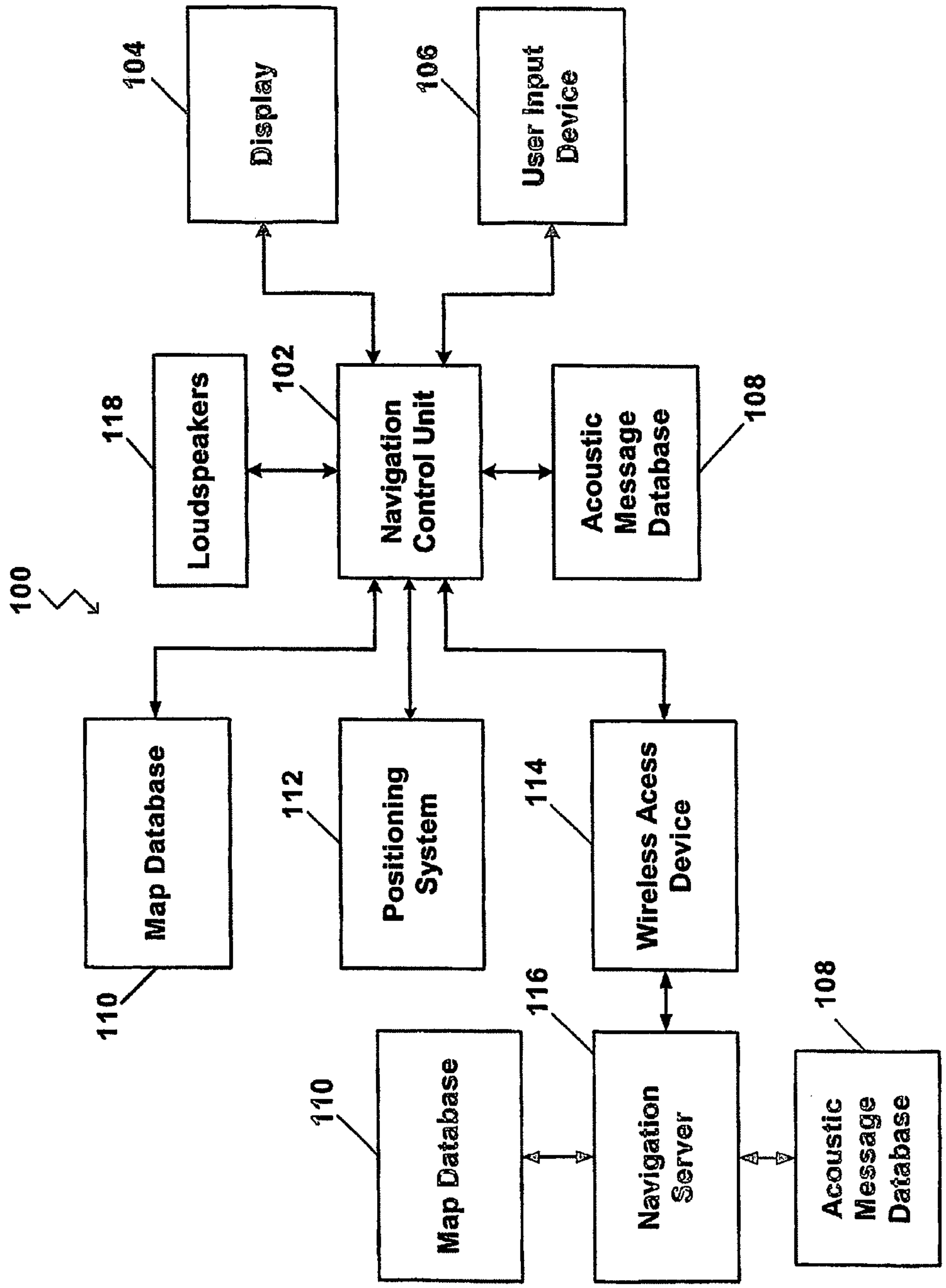

100
104
Display
106
User Input
Device
118
Loudspeakers
102
Navigation
Control Unit
Acoustic
Message
Database
108
Map Database
110
Positioning
System
112
114
Wireless Acess
Device
116
Navigation
Server
110
Map Database
108
Acoustic
Message
Database

Figure 1

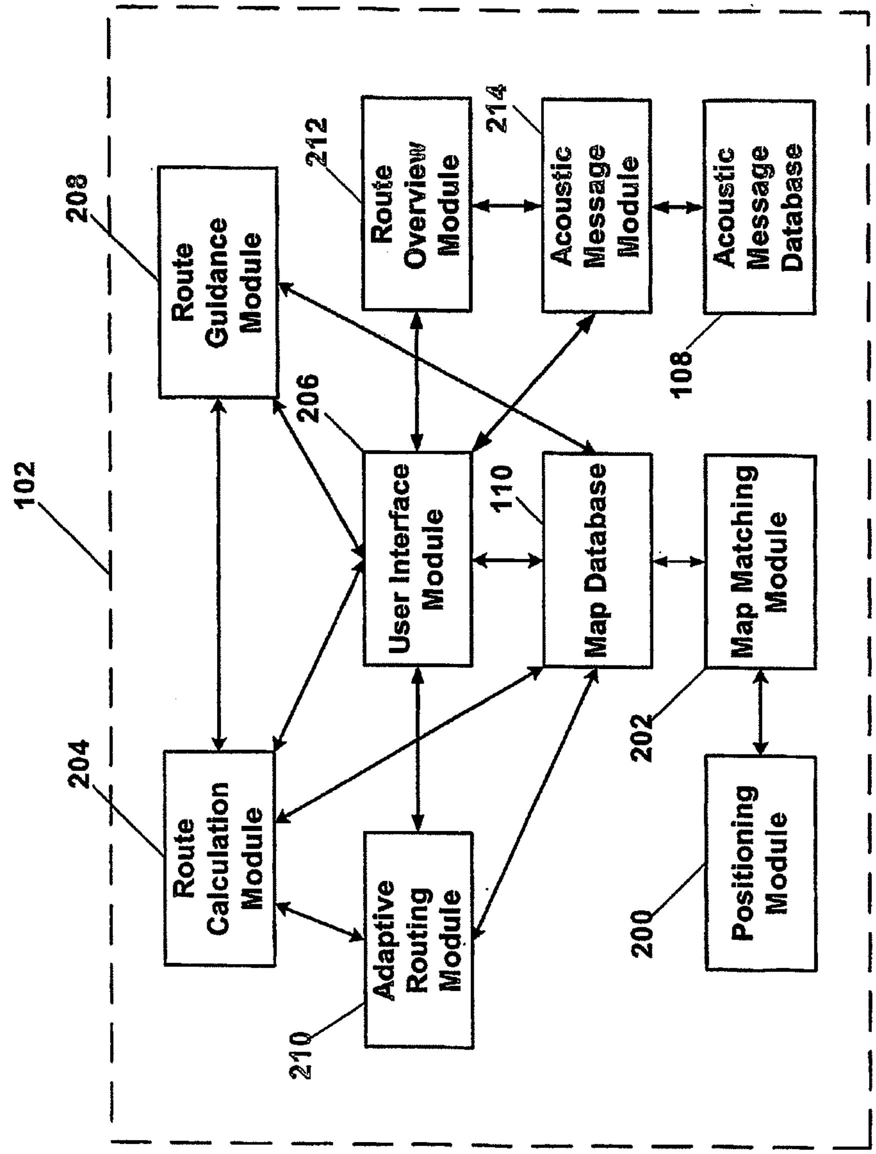
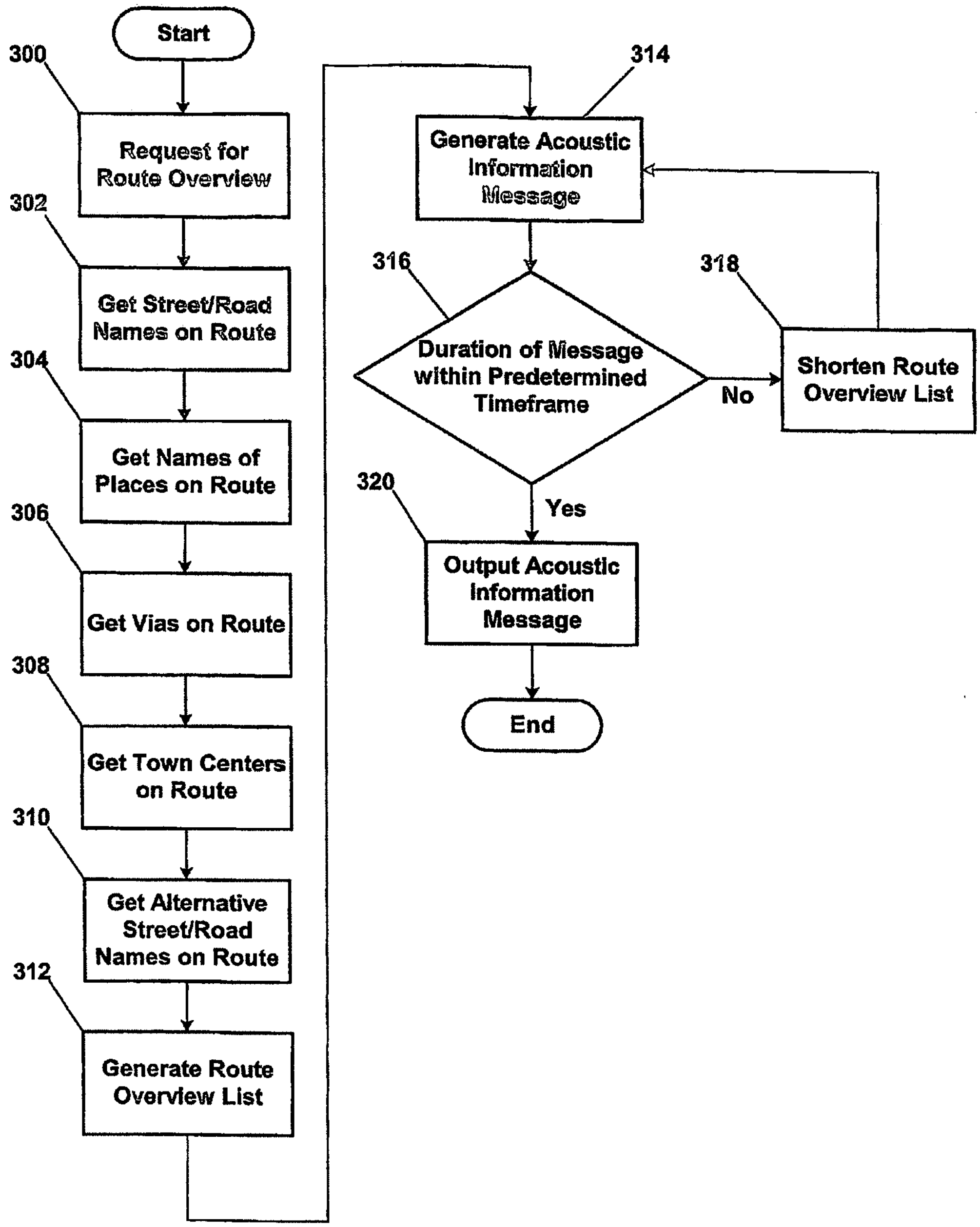

102
208
Route Guidance Module
212
Route Overview Module
214
Acoustic Message Module
Acoustic Message Database
108
206
User Interface Module
110
Map Database
Map Matching Module
202
204
Route Calculation Module
Adaptive Routing Module
210
200
Positioning Module

Figure 2



Start
300
Request for Route Overview
302
Get Street/Road Names on Route
304
Get Names of Places on Route
306
Get Vias on Route
308
Get Town Centers on Route
310
Get Alternative Street/Road Names on Route
312
Generate Route Overview List
314
Generate Acoustic Information Message
316
Duration of Message within Predetermined Timeframe
No
318
Shorten Route Overview List
Yes
320
Output Acoustic Information Message
End

Figure 3

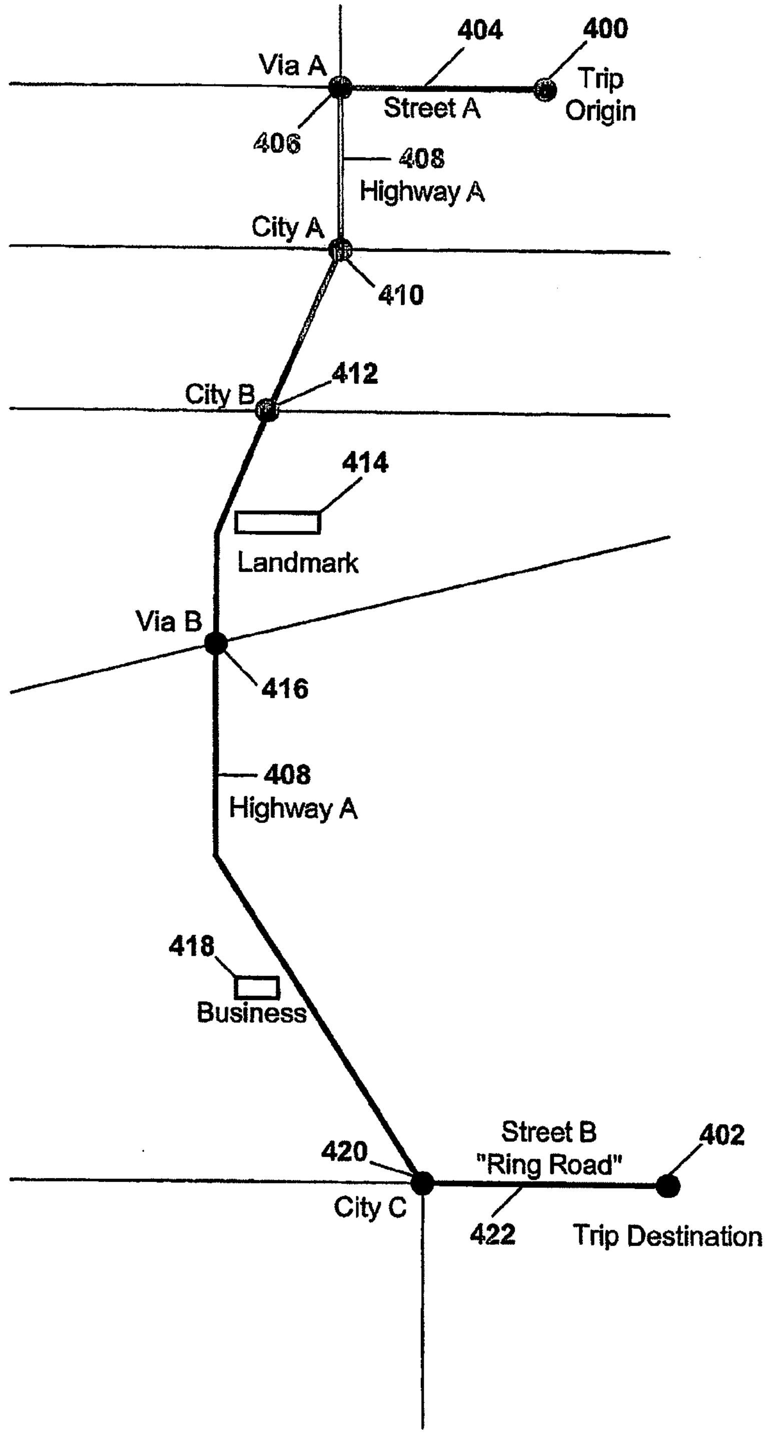

404
400
Via A
Trip
Origin
Street A
406
408
Highway A
City A
410
412
City B
414
Landmark
Via B
416
408
Highway A
418
Business
Street B
"Ring Road"
402
420
City C
422
Trip Destination

Figure 4

NAVIGATION SYSTEM WITH ACOUSTIC ROUTE INFORMATION

BACKGROUND OF THE INVENTION

[0001] 1. Technical Field

[0002] This invention relates generally to vehicle navigation systems and, more particularly, to generating acoustic route information in a vehicle navigation system.

[0003] 2. Related Art

[0004] Vehicle navigation systems are becoming increasingly popular in the automobile industry. A typical vehicle navigation system includes a global positioning system ("GPS") receiver that is mounted somewhere on the vehicle. The GPS receiver is capable of communicating with a satellite-based global positioning system or other localized positioning systems. The GPS receiver obtains position information that is converted into some form of display for the vehicle operator indicating the position of the vehicle relative to previously determined reference points or other known landmarks in a given map database.

[0005] The typical vehicle navigation system also includes a digital map database module that includes digitized map information that can be processed by a navigation computer designed to handle map-related functions. A map matching module is used to match the position or trajectory measured by a positioning module to a position associated with a location or route on a map provided from the digital map database. The positioning module receives its information from the GPS receiver.

[0006] A route planning module is also typically included that is used to help vehicle drivers plan a route prior to or during a trip. A commonly used technique is to find a minimum-travel-cost route, which is designed to minimize the amount of distance traveled and costs associated with reaching a predetermined destination. A route guidance module is also included that is used to guide the driver along the route generated by the route planning module. Guidance can be given, either before the trip, or in real time while en-route. The real time or en-route guidance is typically generated using optical driver recommendations and/or acoustic driver recommendations.

[0007] The typical vehicle navigation system also includes a human-machine interface module that provides users with a way to interact with the location and navigation computer and devices. A visual display is typically used to convert signals into a visual image in real time for direct interpretation by the user. As such, displays are used to provide the optical driver recommendations. The display itself is typically an electro-optical device such as a liquid crystal display ("LCD"), a cathode-ray tube ("CRT") display, an electroluminescent display ("ELD"), a heads-up display ("HUD"), a plasma display panel ("PDP"), a vacuum fluorescent display ("VFD"), or a touch-screen display.

[0008] The human-machine interface module may also include a voice-based interface that allows the user to interact with vehicle navigation system. The acoustic driver recommendations are provided using the voice-based interface. Speech is the most common interface that is used for delivering acoustic driver recommendations because it provides a natural interface that does not distract the driver from operating the vehicle and paying attention to the roadway. As such, information provided through acoustic driver recommendations may be safer because it allows the vehicle operator to concentrate on the task of driving.

[0009] Travelers using a subway or railway station are typically provided with a short information message about the time of departure and the route of the train. Existing navigation systems for vehicles currently do not provide this functionality. Drivers can ascertain the anticipated time of arrival, the distance to be traveled and the computed route, but the user is not provided with a comprehensive overview of the entire route to be taken. As such, this information does not give the driver any possibility of preparing himself/herself for the route being traveled.

[0010] Some navigation systems provide visual route lists that contain all of the official road names of the roads along the route to be taken. Drivers who are not familiar with the surroundings are not in a position to derive even a rough sketch of the route based on the visual route list. The direction of the route must therefore be figured out on a map. Although a map illustration provides a good overview of the direction of the route, it does require the capacity to abstract. Generally, the displays that are used in navigation systems are too small to depict the names of town parts or road structures. As such, a need exists for a way to provide drivers with an overview of the route being taken to reach a predetermined destination.

[0011] A navigation system capable of providing an acoustic route overview message summarizing a route to a predetermined destination is disclosed. The navigation system includes a route calculation module, a route overview module and an acoustic message module. The route calculation module is used to calculate a route to the predetermined destination. The route overview module is used to create a route overview list that is based on the route to be traveled to reach the destination. The acoustic message module is operable to generate an acoustic route overview message based on the route overview list that is associated with the route. The acoustic route overview message is an audible summary of the route to be taken by the vehicle to reach the predetermined destination.

[0012] Once the acoustic message module generates the acoustic route overview message, it is audibly reproduced on at least one loudspeaker that is located in the vehicle. The acoustic route overview message is output in response to a request for a route overview that is entered by a user. The request for the route overview may be entered by pressing a button, by setting an option, or by audibly requesting a route overview. The route overview list that is generated by the route overview module may include at least one item that may be selected from a group of items including a street name on the route, a name of a place on the route, a via on the route, a city on the route, an alternative street name on the route, a business location on the route, and a landmark on the route.

[0013] The acoustic route overview message may be limited to a predetermined amount of time. The route overview list may be shortened based on a variety of weighting factors to fit within the predetermined amount of time. The weighting factor may be a function of a popularity ranking that may be associated with each item contained in the route overview list. The more popular an item is in the list the less likely it

will be eliminated from the list. The predetermined weighting factor may also be based on a length of a road segment to be traveled on the route. The longer the road segment is the less likely that particular road segment will be eliminated from the acoustic route overview message. The acoustic route overview message may also include an anticipated time of arrival that is placed in the message by the acoustic message module.

[0014] The navigation system may also be designed in the form of a server-based solution. A navigation control unit may be connected to a navigation server by using a wireless access device. The wireless access device transmits data to and from the navigation control unit to the navigation server. The route to be traveled to reach the destination, the route overview list and the acoustic route overview message may all be accomplished on the navigation server. The navigation server performs most of the computing tasks and stores a map database and an acoustic message database that are used during operation.

[0015] Other systems, methods, features and advantages of the invention will be, or will become, apparent to one with skill in the art upon examination of the following figures and detailed description. It is intended that all such additional systems, methods, features and advantages be included within this description, be within the scope of the invention, and be protected by the following claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The invention can be better understood with reference to the following drawings and description. The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention. Moreover, in the figures, like reference numerals designate corresponding parts throughout the different views.

[0017] **FIG. 1** is a block diagram of a vehicle navigation system.

[0018] **FIG. 2** is a block diagram of application modules located on the navigation system.

[0019] **FIG. 3** is a flow chart of exemplary process steps performed to generate acoustic route overview messages on the navigation system.

[0020] **FIG. 4** is an exemplary road network map from a trip origin to a trip destination.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0021] Referring to **FIG. 1**, a navigation system **100** capable of providing acoustic route information is disclosed. As illustrated, the navigation system **100** includes a navigation control unit **102** that includes software modules programmed to calculate routes from points of origin to predetermined destinations. Although not specifically illustrated, the navigation control unit **102** may include a Central Processing Unit ("CPU"), a system bus, a Random Access Memory ("RAM"), a Read Only Memory ("ROM"), an I/O adapter for connecting peripheral devices such as hard disc drives, CD-ROM drives, a communications adapter, and a display adapter. Those skilled in the art should recognize that various computing devices may be used as the navigation control unit **102**.

[0022] The navigation control unit **102** may be connected with a display **104**. The display **104** may be a touch-screen display that can function as both a display and a user input device. The navigation control unit **102** may be connected with a user input device **106**. The user input device **106** may be a keypad, buttons, knobs, a personal computer, a laptop computer, a pocket PC, a personal digital assistant, a wireless access device or phone, or any other type of computing device that is capable of allowing a user of the navigation system **100** to input data during operation.

[0023] If the user input device **106** communicates wirelessly with the navigation control unit **102**, both the navigation control unit **102** and the user input device **106** may be connected with a wireless communication device that is capable of passing the necessary data back and forth between the user input device **106** and the navigation control unit **102**. Some illustrative methods of connecting the user input device **106** with the navigation control unit **102** that may be used include infrared, Bluetooth, wireless LAN, Universal Serial Bus, fiber optic, direct wire, parallel ports, serial ports, and a network connection.

[0024] The navigation system **100** also includes an acoustic message database **108**. The acoustic message database **108** is connected to the navigation control unit **102**. The acoustic message database **108** includes a plurality of acoustic messages that may fall within any one of a number of categories. The acoustic messages may be stored on a hard disc storage device, a CD-Rom, or any other suitable storage medium. The acoustic messages may include street/road names and numbers, motorway names and numbers, highway names and numbers, via identifiers, city names, town names, town center names, town part names, alternative street/road names, landmark names, famous structure names, building names, traffic information messages, and business names (e.g.—restaurants, hotels, shopping centers and so forth). For the purpose of the present invention, all of the above-mentioned acoustic messages may be called route information points.

[0025] As further illustrated, the navigation control unit **102** may be connected to a map database **110**. The map database **110** may be located on a hard disc storage device, a CD-Rom, or any other suitable storage medium. The map database **110** contains a digital map of a road network for various geographic locations as well as other types of data. The map database **110** allows the navigation control unit **102** to display a map of a geographic location including road networks. The navigation control unit **102** can help locate an address or destination using a street address or nearby intersections, can help calculate a travel route, can match sensor-detected vehicle trajectory with a known road network to determine more accurately the actual position of the vehicle; or provide travel information such as travel guides, landmarks, hotel and restaurant information.

[0026] The navigation control unit **102** may also be connected to at least one positioning system **112**. The positioning system **112** may be used to determine the geographic location or coordinates of the vehicle, as well as the trajectory of the vehicle. Positioning involves the determination of the geo-coordinates of the vehicle on the surface of the Earth. Knowing the position of the vehicle allows the navigation control unit **102** to determine the precise position of the vehicle relative to a road network map. The navigation

control unit **102** is also able to provide maneuvering instructions to the driver of the vehicle by knowing the geographic location of the vehicle.

[0027] Three types of positioning systems **112** that may be used include a stand-alone system, a satellite-based system, and a terrestrial radio based system. A dead reckoning system is an illustrative stand-alone system that may be used by the disclosed navigation system. A satellite-based system that may be used involves equipping the vehicle with a global positioning system ("GPS") receiver or any other type of system that uses satellites to determine geographic locations. A terrestrial radio based system is a system that uses measurement techniques to determine the location of the vehicle. Three commonly used measurement techniques for terrestrial positioning are estimated time of arrival ("ETA"), direction of arrival ("DOA"), and time difference of arrival ("TDOA"). A combination of all of the above-referenced positioning systems, as well as others, may be used in the disclosed navigation system **100**.

[0028] A wireless access device **114** may be connected with the navigation control unit **102**. The wireless access device **114** may be operable to connect the navigation control unit **102** with a navigation server **116**. Route calculation and data storage may be accomplished by the navigation server **116**. This represents a server-based solution in which the majority of the processing occurs at the navigation server **116** as opposed to the navigation control unit **102** of the vehicle navigation system **100**. The navigation control unit **102** logs into the navigation server **116** using the wireless access device **114** and a wireless data transmission protocol (such as WAP) may be used to transmit data and route planning information generated by the navigation server **116** to the navigation control unit **102**.

[0029] The navigation server **116** may be connected to the acoustic message database **108** and the map database **110**. As such, during operation the data stored in these respective databases may be retrieved by the navigation server **116**. This would eliminate the need for the navigation system **100** in the vehicle to retain such data. For example, the driver of the vehicle would not be responsible for ensuring that the proper CD-Rom was placed in the navigation system **100** for the particular geographic location in which he or she is traveling. Although illustrated separately, the acoustic message database **108** and the map database **110** may be stored in or on the same storage medium.

[0030] The navigation control unit **102** may also be connected with a plurality of loudspeakers **118**. The loudspeakers **118** may be used to generate audible sounds that are produced for the benefit of the driver, such as driving directions. In addition, the loudspeakers **118** may be used to play music or any other type of audible sound. As set forth in greater detail below, for the purpose of the present invention the loudspeakers **118** are used to audibly reproduce an acoustic overview of the route to be taken to reach a predetermined destination.

[0031] Referring to **FIG. 2**, the navigation control unit **102** includes a digital map database **110**. The digital map database **110** contains map information in a predefined format that may be capable of being read and used by the navigation control unit **102** or the navigation server **116**. The navigation control unit **102** is capable of using the map information for map related functions such as identifying and providing locations, road classifications, road names, traffic regulations, and travel information. The map database **110** also preferentially contains road network maps of various geographic locations. The road network maps include nodes/vias and segments that make up road networks that are used by vehicles to travel to predetermined destinations. The map database **110** may also contain hierachial "weight" information about streets (street class), highways (highway class), buildings (importance), town names (town size) as well as other weight factors about different items that may be contained in the map database **110**. As set forth in detail below, this information is used to calculate a weighting factor and to shorten a route overview list.

[0032] A positioning module **200** may be included on the navigation control unit **102** that is operable to determine the geographic location and trajectory of the vehicle using the positioning system **112**. As set forth above, several different positioning systems **112** may be used to determine the trajectory and geographic position of the vehicle. The positioning module **200** may include an integration algorithm that takes output signals generated by various positioning systems **112** to determine the precise geographic location and trajectory of the vehicle.

[0033] Once the geographic location and trajectory of the vehicle have been determined, a map matching module **202** may be used to match the geographic location of the vehicle with a position on the road network map generated with the map database **110**. A map-matching algorithm of the map matching module **202** may be used to place the vehicle in the proper location on the road network map. The map matching module **202** is capable of correlating the vehicle position and trajectory as a function of inputs from various positioning systems **112** to the road network map by comparing the vehicle trajectory and location with the routes present in the map database **110**.

[0034] The navigation control unit **102** may also include a route calculation module **204**. Route calculation is the process of planning a route prior to or during a trip to a predetermined destination. The route calculation module **204** may use a shortest path algorithm to determine a recommended route from a trip origin to a trip destination. In the server-based solution, the navigation server **116** may include the route calculation module **204**. Those skilled in the art of vehicle navigation systems would recognize that several different shortest path algorithms and variations of shortest path algorithms may be used in the navigation system **100** and is beyond the scope of the present invention.

[0035] The shortest path algorithm may also include a route optimization module that uses planning criteria to plan the route. The quality of any given route may depend on many factors and selection criteria such as distance, road types, speed limits, location, number of stops, number of turns and traffic information. The route selection criteria can either be fixed at manufacture or may be implemented through a user interface module **206**. Determination of the best route may use the selection criteria and a digital road network map retrieved from the map database **110** to minimize distance and travel time.

[0036] As illustrated in **FIG. 2**, the navigation control unit **102** may also include a user interface module **206**. The user interface module **206** may be operable to generate a graphical user interface ("GUI") on the display **104**. The user

interface module **206** may also be operable to allow a user to interact with the navigation system **100** and enter inputs into the navigation system **100**. The user interface module **206** may receive inputs from the display **104** if it is a touch-screen display. The user input device **106** may also be used to enter inputs into the user interface module **206**. The user inputs may be transmitted to the route calculation module **204**.

[**0037**] The navigation control unit **102** may also include a route guidance module **208**. The route guidance module **208** may be used to guide the driver along the route generated by the route calculation module **204**. The route guidance module **208** may use the positioning module **200**, the map database **110**, and the map matching module **202** to guide the driver along the route to the respective destination. The route guidance module **208** may also allow the user interface module **206** to generate a road network map GUI on the display **104** that illustrates where the vehicle is located on a road network map and the direction the vehicle is traveling.

[**0038**] As further illustrated in **FIG. 2**, the navigation control unit **102** may also include an adaptive routing module **210**. The adaptive routing module **210** allows the driver of the vehicle to change or modify a calculated route based on user defined specifications. The driver of the vehicle may open or close nodes or segments of roads on a digital map, thereby allowing the driver to influence how a given route is calculated. For example, if a driver wants to avoid a certain road or segment of road, he or she may close that segment and then the adaptive routing module **210** will calculate a new route based on the user input.

[**0039**] The navigation control unit **102** may also include a route overview module **212**. The route overview module **212** is responsible for generating a route overview list. The route overview list contains a list of items that are associated with the route to be traveled to reach a predetermined destination. The list of items that are associated with the route to be traveled, or being traveled, may include vias or nodes on the route, numbers of classified streets (motorways and highways) on the route, towns on the route, street or road names on the route, alternative road names on the route, names of places on the route, landmarks on the route, and business locations on the route. The route overview list is a general survey or summary of the route to be traveled. As such, the route overview list is an overview of the path that the vehicle will travel to reach the designated destination.

[**0040**] The navigation control unit **102** may also include an acoustic message module **214**. Once the route overview list has been generated, the acoustic message module **214** may be responsible for generating an acoustic route overview message that may be played to the driver using the loudspeakers **118**. The acoustic message module **214** may use the acoustic message database **108** to generate the acoustic overview message. The acoustic route overview message is generated as a function of the route overview list that is generated by the route overview module **212**. The acoustic message module **214** may use a text to speech engine to convert textual data contained in the acoustic message database **108** into audible human speech.

[**0041**] Referring to **FIG. 3**, a block diagram of the exemplary tasks performed by the route overview module **212** and the acoustic message module **212** are illustrated. At step **300**, the driver or occupant of the vehicle may enter a request for a route overview. The driver or occupant of the vehicle may enter the request for the route overview using a respective user input device **106**. For example, the navigation control unit **102** may be connected with an "INFO" button on a head unit that may be used to enter a request for the route overview. Pressing the INFO button will cause the navigation control unit **102** to generate the route overview and play an acoustic message of the route overview to the occupants of the vehicle.

[**0042**] In response to the request for the route overview, the route overview module **212** generates a list of items associated with the route. The items that may be included, which are represented as steps **302-310** in **FIG. 3**, are the street or road names on the route (step **302**), the names of places on the route (step **304**), the vias or nodes on the route (step **306**), the town centers on the route (step **308**) and the alternative street or road names on the route (step **310**). Although not specifically illustrated, the items on the list may also include the names of businesses on the route, the names of buildings on the route or the names of landmarks on the route. For example, if the calculated route takes the vehicle past the White House and the Lincoln Memorial in Washington, D.C., the route overview list may include these items. In addition, if the route takes the vehicle past the international headquarters for Harman International Industries, Inc. this may be included as well.

[**0043**] After the aforementioned items are obtained, a route overview list may be generated by the route overview module **212**, which is represented as step **312**. Once the route overview list is generated, at step **314** the acoustic message module **214** uses the route overview list to generate an acoustic route overview message. The acoustic message module **214** uses the route overview list to obtain acoustic messages from the acoustic message database **108** that match items contained in the route overview list. Although not specifically illustrated in **FIG. 3**, after the acoustic route overview message is generated it may be played or audibly reproduced on the loudspeakers **118**.

[**0044**] As set forth above, the navigation system **100** also includes an acoustic message database **108**. The acoustic message database **108** is connected to the navigation control unit **102**. The acoustic message database **108** includes a plurality of acoustic messages that may fall within any one of a number of categories. The acoustic messages may be stored on a hard disc storage device, a CD-Rom, or any other suitable storage medium. The acoustic messages may include street/road names and numbers, motorway names and numbers, highway names and numbers, via identifiers, city names, town names, town center names, town part names, alternative street/road names, landmark names, famous structure names, building names, traffic information messages, and business names (e.g.—restaurants, hotels, shopping centers and so forth). For the purpose of the present invention, all of the above-mentioned acoustic messages may be called route information points.

[**0045**] Another feature of the navigation system **100** involves tailoring the acoustic route overview message based on predetermined criteria. As illustrated in **FIG. 3**, after the acoustic route overview message is generated, the acoustic message module **214** may determine if the duration of the message fits within a predetermined timeframe, which is illustrated at step **316**. For example, the acoustic message

module **214** may limit the duration of the acoustic route overview message to a timeframe of ten seconds.

[0046] If the acoustic route overview message does not fit within the predetermined timeframe, at step **318** the acoustic message module **214** may shorten the route overview list to fit within the predetermined timeframe. The route overview list may be shortened by simply eliminating items from the list or may be shortened based on a plurality of weighting factors. The weighting factors may be based on a popularity ranking of an item contained in the route overview list or on a length of a road section or segment to be traveled on the route. Items contained in the route overview list may have a popularity ranking associated with them such that items having a low popularity ranking are eliminated before items that have a higher popularity ranking. In addition, items contained on short road segments to be traveled may be eliminated before items contained on long road segments. Once the acoustic route overview message has been shortened to fit within the predetermined audio time period, at step **320** the acoustic route overview message is output on the loudspeakers **118**.

[0047] **FIG. 4** illustrates an exemplary road network map that represents a route that a vehicle may take to a predetermined destination. The road network map is for illustrative purposes only and should not be construed as a limitation of the present invention. The route includes a trip origin **400** and a trip destination **402**. As set forth above, during operation if an occupant of the vehicle requests a route overview the route overview module **212** generates a route overview list. The occupant of the vehicle may request a route overview by pressing a button on the head unit, using voice commands or by using any other type of input device.

[0048] The route overview list generated by the route overview module **212** for the route to the trip destination **402** illustrated in **FIG. 4** may include the following items: Street A **404**, Via A **406**, Highway A **408**, City A **410**, City B **412**, Landmark **414**, Via B **416**, Business **418**, City C **420**, Street B "Ring Road"**422** and the trip destination **402**. Once the route overview list is created by the route overview module **212**, the acoustic message module **214** uses the route overview list to create an acoustic route overview message. The acoustic message module **214** uses the items contained in the route overview list to locate audible messages contained within the acoustic message database **108** that are associated with the items contained in the route overview list.

[0049] Once the audible messages are located in the acoustic message database, the acoustic message module **214** generates the acoustic route overview message. In the example set forth above, the acoustic message module **214** may create the following acoustic route overview message: "The route to your trip destination goes via Street A to Via A, Highway A through City A and City B, pass Landmark A through Via B, pass Business A to City C, Street B, also known as Ring Road, in City C to your trip destination. Anticipated arrival time: **23** minutes past 12 o'clock." As set forth above, the acoustic route overview message includes the names of streets, highways, vias, landmarks, businesses and alternative road or street names (e.g.—"Ring Road"). The acoustic route overview message may also include an anticipated time of arrival message as well.

[0050] The acoustic route overview message may also be shortened by using the weighting factors set forth above. The acoustic route overview message may be shortened so that it will fit within a predetermined timeframe. This would be especially helpful for longer trips that include allot of items in the route overview list. For example, if the acoustic route overview message is shortened based on the popularity rankings of items contained in the route overview list, the vias (Via A **406** and Via B **416**) may be eliminated from the acoustic route overview message. If the route overview message is shortened by using the length of road segments as the determining factor, then Street A **404** may be eliminated from the list because it is a relatively short road segment. The longest road segment, which is Highway A **408** in the example set forth above, would likely not be eliminated because it is the longest road segment.

[0051] Referring once again to **FIGS. 1 and 2**, as previously set forth the navigation control unit **102** may be connected with the navigation server **116**. During operation the navigation control unit **102** communicates with the navigation server **116** using the wireless access device **114**. In this embodiment, the navigation server **116** may include some of the software modules set forth in **FIG. 2**. As such, some of the computations set forth above would be accomplished on the navigation server **116** and then the data from those computations would be transmitted to the navigation control unit **102** using the wireless access device **114**. For example, the route overview module **212** and the acoustic message module **214** may be located on the navigation server **116**. The acoustic route overview message that is generated by the acoustic message module **214** would be transmitted to the navigation control unit **102**.

[0052] While various embodiments of the invention have been described, it will be apparent to those of ordinary skill in the art that many more embodiments and implementations are possible within the scope of the invention. Accordingly, the invention is not to be restricted except in light of the attached claims and their equivalents.

What is claimed:

1. A navigation system, comprising:

a route calculation module for calculating a route to a predetermined destination;

a route overview module for creating a route overview list as a function of the route; and

an acoustic message module for generating at least one acoustic route overview message based on the route overview list associated with the route.

2. The navigation system of claim 1 where the acoustic route overview message is output on at least one loudspeaker.

3. The navigation system of claim 1 where the acoustic route overview message is output in response to a request for a route overview entered by a user.

4. The navigation system of claim 1 where the route overview list includes at least one item selected from a group of items including a street name on the route, a name of a place on the route, a via on the route, a city on the route, an alternative street name on the route, a business location on the route, and a landmark on the route.

5. The navigation system of claim 1 where the acoustic route overview message is limited to a predetermined amount of time.

6. The navigation system of claim S where the route overview list is shortened based on at least one predetermined weighting factor to fit within the predetermined amount of time.

7. The navigation system of claim 6 where the predetermined weighting factor is a function of a popularity ranking associated with each item contained in the route overview list.

8. The navigation system of claim 6 where the predetermined weighting factor is based on a length of a road segment to be traveled on the route.

9. The navigation system of claim 1 where the acoustic route overview message includes an anticipated time of arrival.

10. The navigation system of claim 1 where the acoustic message module retrieves at least one audio file from an acoustic message database to generate the acoustic route overview message.

11. A method of generating acoustic route information in a navigation system, comprising the steps of:

calculating a route to a predetermined destination;

creating a route overview list based on the route to the predetermined destination; and

generating an acoustic route overview message as a function of the route overview list.

12. The method of claim 11 further comprising the step of audibly reproducing the acoustic route overview message on at least one loudspeaker.

13. The method of claim 11 where the acoustic route overview message is audibly reproduced in response to a request from a user.

14. The method of claim 11 where the route overview list is determined by a route overview module.

15. The method of claim 11 where the route overview list includes at least one item selected from a group of items including a street name on the route, a name of a place on the route, a via on the route, a city on the route, an alternative street name on the route, a business location on the route, and a landmark on the route.

16. The method of claim 11 where the acoustic route overview message is limited to a predetermined amount of time.

17. The method of claim 16 where the route overview list is shortened based on at least one predetermined weighting factor to fit within the predetermined amount of time.

18. The method of claim 17 where the predetermined weighting factor is a function of a popularity ranking associated with each item contained in the route overview list.

19. The method of claim 17 where the predetermined weighting factor is based on a length of a road segment to be traveled on the route.

20. The method of claim 11 where the acoustic route overview message includes an anticipated time of arrival.

21. The method of claim 11 where the acoustic route overview message is generated by an acoustic message module.

22. The method of claim 21 where the acoustic message module retrieves at least one audio file from an acoustic message database to generate the acoustic route overview message.

23. A navigation system, comprising:

route calculation means for calculating a route to a predetermined destination;

route overview means for creating a route overview list as a function of the route; and

audio signal generation means for generating an acoustic route overview message based on the route overview list.

24. The navigation system of claim 23 where the route overview means comprises a route overview module.

25. The navigation system of claim 23 where the acoustic route overview message is audibly reproduced on at least one loudspeaker.

26. The navigation system of claim 23 where the acoustic route overview message is audibly reproduced in response to a request from a user.

27. The navigation system of claim 23 where the route overview list includes at least one item selected from a group of items including a street name on the route, a name of a place on the route, a via on the route, a city on the route, an alternative street name on the route, a business location on the route, and a landmark on the route.

28. The navigation system of claim 23 where the acoustic route overview message is limited to a predetermined amount of time.

29. The navigation system of claim 28 where the route overview list is shortened based on at least one predetermined weighting factor to fit within the predetermined amount of time.

30. The navigation system of claim 29 where the predetermined weighting factor is a function of a popularity rankig associated with each item contained in the route overview list.

31. The navigation system of claim 29 where the predetermined weighting factor is based on a length of a road segment to be traveled on the route.

32. The navigation system of claim 23 where the acoustic route overview message includes an anticipated time of arrival.

33. The navigation system of claim 23 where the acoustic route overview message is generated by an acoustic message module.

34. The navigation system of claim 33 where the acoustic message module retrieves at least one audio file from an acoustic message database to generate the acoustic route overview message.

35. A navigation system, comprising:

a navigation control unit connected with a navigation server;

a route calculation module located on the navigation server for calculating a route to a predetermined destination;

a route overview module located on the navigation server for creating a route overview list based on the route; and

an acoustic message module located on the navigation server for generating an acoustic route overview message as a function of the route overview list.

36. The navigation system of claim 35 where the navigation control unit is connected with the navigation server by a wireless access device.

37. The navigation system of claim 36 where the navigation server transmits the acoustic route overview message to the navigation control unit using the wireless access device.

38. The navigation system of claim 35 where the route overview list includes at least one item selected from a group of items including a street name on the route, a name of a place on the route, a via on the route, a city on the route, an alternative street name on the route, a business location on the route, and a landmark on the route.

39. The navigation system of claim 35 where the acoustic route overview message is limited to a predetermined amount of time.

40. The navigation system of claim 35 where the acoustic route overview message includes an anticipated time of arrival.

41. The navigation system of claim 35 where the acoustic message module retrieves at least one audio file from an acoustic message database to generate the acoustic route overview message.

42. A method of generating acoustic route information, comprising the steps of:

calculating a route to a predetermined destination with a navigation server;

creating a route overview list based on the calculated route to the predetermined destination with the navigation server;

generating an acoustic route overview message as a function of the route overview list; and

transmitting the acoustic route overview message to a navigation control unit.

43. The method of claim 42 where the acoustic route overview message is transmitted to the navigation control unit using a wireless access device.

44. The method of claim 42 further comprising the step of audibly reproducing the acoustic route overview message on at least one loudspeaker.

45. The method of claim 42 where the route overview list includes at least one item selected from a group of items including a street name on the route, a name of a place on the route, a via on the route, a city on the route, an alternative street name on the route, a business location on the route, and a landmark on the route.

46. The method of claim 42 where the acoustic route overview message is limited to a predetermined amount of time.

47. The method of claim 42 where the acoustic route overview message includes an anticipated time of arrival.

48. The method of claim 42 where the acoustic route overview message is generated by an acoustic message module.

49. The method of claim 48 where the acoustic message module retrieves at least one audio file from an acoustic message database to generate the acoustic route overview message.

* * * * *

EXHIBIT 8

Back Seat Driver: voice assisted automobile navigation

by

James Raymond Davis

B.S.A.D., Massachusetts Institute of Technology (1977)

Submitted to the Media Arts and Sciences Section
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

September 1989

Signature of Author ....
Media Arts and Sciences Section
August 4, 1989

Certified by ....
Nicholas P. Negroponte
Professor of Media Technology
Thesis Supervisor

Accepted by ....
Stephen A. Benton
Chairman, Departmental Committee on Graduate Students

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Abstract

The Back Seat Driver is a computer navigation assistant for drivers in a city. It differs from earlier navigation programs by using speech, rather than graphics, to give instructions. The advantages of speech are that the driver's eyes are left free for driving and that the spoken directions contain information not easily portrayed in pictures. The program talks about the features of the road in the same way the driver sees them, giving the impression that the program is actually is in the car.

Driving instructions are modeled after those given by people. The two issues for spoken directions are *what to say* (content) and *when to say it* (timing). The content of the instructions tells the driver what to do and where to do it. The program has a large taxonomy of intersection types, and chooses verbs to indicate the kind of intersection and the way of moving through it. The instructions refer to landmarks and timing to tell the driver when to act.

Timing is critical because speech is transient. Drivers hear instructions just in time to take the required action, and thus need not remember the instruction or exert effort looking for the place to act. The program also gives instructions in advance, if time allows, and the driver may request additional instructions at any time. If the driver makes a mistake the program describes the mistake, without casting blame, then finds a new route from the current location.

Street map data bases for navigation programs must distinguish between *physical* connectivity (how pieces of pavement connect) and *legal* connectivity (whether one can legally drive onto a physically connected piece of pavement). Legal connectivity is essential for route finding, and physical connectivity for describing the route. The database must also contain all landmark information, since the program has no "eyes".

Chapter 2

Human Direction Giving

My investigations began by studying how people give directions when they are passengers in the car. The intent was to discover common patterns in the directions that could be duplicated by the Back Seat Driver. The number of subjects (six) was far too small to justify any general conclusions about direction giving, but that was not the intention. I studied human direction giving to get a starting point for the design of the Back Seat Driver, not an ending point. I built the Back Seat Driver through an iterative process of design, test, and modification which converged to the system described in this thesis. All I needed was a good first approximation, and a sense of the kinds of variation in direction giving style, and for this I think six subjects was sufficient.

Procedure

My six subjects told me how to drive to destinations of their choosing while riding in the car. All were experienced drivers. The subjects actually wanted to

go to their destination, so they had an incentive to give good directions. (They did not all provide the best routes, but route finding was not a subject of this investigation.) Most, but not all, of their utterances were spontaneous. In some cases I asked questions - "What now?" or "How long will I be on this road?". Our conversations were recorded on a cassette recorder in the car. All talk relevant to the route was transcribed, but most personal conversation was not transcribed. The transcriptions included approximate position of the car, as determined from memory. A sample transcription appears at the end of this chapter.

There are limits to the usefulness of this method. By its very nature, there is no way to control for the route or the destination. No two trips led to the same destination, though several had common beginnings. I assume that there is nothing special about the routes, so I can generalize. The usefulness of this data depends upon the assumption that the subjects were competent to give instructions and that the instructions were in the same form that subjects would have wanted to hear, had they been the driver. There is certainly some doubt about this point. We could do better than to emulate subjects who hesitated, gave misleading directions, or simply pointed[1]. Another limitation is that the transcriptions show position only coarsely, and velocity not at all, so they can not be used to answer questions of timing.

Overview

My understanding of driving instructions comes from treating driving as decision making. I think of the driver as constantly aiming the car at a moving target, a patch of pavement some few yards ahead. The driver is making a new decision several times a second. Some of these decisions involve choosing the next street to go along. When following instructions, at each point of decision one of two con-

[1]In fact, some navigation systems do no more than point in the right direction.

ditions must apply: either the instructions must say explicitly what to do, or the driver and instruction-giver must mutually believe that the thing to do is obvious and does not need to be said. This is by far the more common condition. It is only at an intersection that there is any meaningful choice, and even there there is a presumption that drivers will continue forward. Giving instructions should be the exception, not the rule. The traditional "back seat driver" - the annoying critic, not the program I built - bothers the driver by giving frequent warnings about conditions the driver is perfectly aware of, acting as if the driver had no common sense.

Navigators must give the driver the information she needs at the time she needs it. At the most basic level, this information consists of **instructions**. Instructions concern what to do and when (or where) to do it. People also provide **advice** which concerns unseen conditions ahead that the instruction giver can anticipate based on experience. The driver can ignore advice, but it may then be harder to follow the instructions. There is also **orientation** information, describing the surroundings, and placing the route in a larger image of the city. Instructions are essential; advice helpful; and orientation optional. Although I think orientation is important for future investigation, I do not address it in this study of natural direction giving.

2.1 Instructions

In the instructions I recorded, people used many different verbs to describe motion through intersections. I believe that people choose particular verbs to help describe the shape of the intersection and the kind of movement through it. One object of this study is to identify the reasons people prefer one verb to another, and the syntactic constructions in which verbs are employed. In addition to the kind of motion, instructions must also specify the direction of motion. This they

do either with the words "left" and "right" or by naming landmarks in the desired direction, or both.

Now let us examine some of the verbs people use.

2.1.1 Verbs

People use a variety of verbs to describe motion through the streets. Table 2.1 lists the ten most common verbs used in directions, in descending order of frequency in my data.

verb	count	verb	count
take	35	turn	4
bear	22	follow	4
go	22	make	3
keep	13	get	3
stay	8	continue	2

Table 2.1: Verbs in descending order of frequency

On what grounds do people choose one verb over another? It would be naive to expect to find a single meaning for each verb. The verb "go" is used in several different contexts – "go straight" and "keep going" and "go right". There is almost no situation where the verb "go" is not used. Fortunately, some other verbs have more restrictive contexts. In this study, I concentrate on the more specific verbs, to the exclusion of the more "generic" ones, on the grounds that automated directions should use the most specific verb that is still correct. The goal is not to reproduce natural speech, with all its complexity. I am not trying to simulate human behavior, I am trying to impart information concisely.

The verb "take" designates a turn. To turn is to change heading by more than (about) 45 degrees, at an intersection where there are always at least two possible

ways to go (though not necessarily both legal). There are two sizes of turns, "hard" turns (more than 90 degrees) and ordinary turns. After a turn, the car is on a "different" street than it was before.

Although the data does not show when two streets are the "same" and when they are "different", it does let us rule out some possible definitions. For instance, it is clear that change of name alone is not sufficient to make a street "different". There are plenty of streets that "change names" at an intersection. For example, if one drives up Ames Street from the Media Laboratory, and crosses Main Street in Kendall Square, the street name changes to Sixth Street. Certainly no one would call this a "turn", and nobody would say they were on a different street, either. Other examples are Hampshire Street in Cambridge, which is called Beacon Street in Somerville; and the O'Brien Highway in Cambridge, which is the McGrath Highway in Somerville (and which, by the way, I have never heard called anything other than McGrath). Aside from these counter-examples, name change can not possibly be the criteria for "different", because many drivers do not even *know* the names of the streets[2].

Change of heading is also not sufficient to make a turn. Near MIT there is an intersection where Fulkerson Street "turns" into Binney Street. An illustration of this place appears in figure 2-1. A driver proceeding up Fulkerson from Main has no choice about which way to go because the street is divided to prevent her from either continuing up Fulkerson or turning left onto Binney. Nobody calls this a turn, even though both angle and name change. Instead, the road seems to be just curving around to the right. This intersection is, in a way, a pun on the word "turn", which, in the phrase "Fulkerson turns into Binney", means "becomes". On the other hand, near Harvard Square there is a place where Appleton Street makes a right hand turn, and the subject whose route passed through this intersection described it as a turn, though the name was the same.

[2]But it will turn out that that the program does have to use names as part of its concept of "different", for reasons explained later.

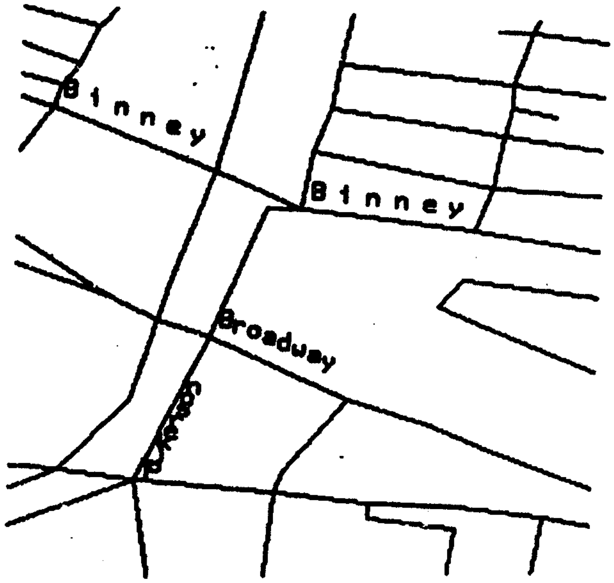

Figure 2-1: Fulkerson turns into Binney

A necessary feature for a "turn" is that there be choice about which way to go, even if the other choice is illegal.

The usual syntactic form for "take" is "take a DIRECTION", where DIRECTION is either "left" or "right". Other verbs with the same meaning as "take", but used less often, are "make", "hang", and "turn". The first two have exactly the same syntax as "take".

To "bear" is to make a lesser change of heading than a turn. After bearing, one may or may not be on a different road. The most common construction is "bear DIRECTION", with variant forms "bear to the DIRECTION" and "bear off to the DIRECTION". In order to "bear" the change in heading must be small and there must also be at least one other road which also requires only a small change in heading. Nobody used the word "bear" to describe the move from Albany Street to Main Street (a change of about 30 degrees). So using the word "bear" not only tells the driver how much turning will be required, it tells something about how the intersection will look. There is an exception. In one case, a subject used the word "bear" to describe motion when there was no choice at all, saying "bear left as the road goes around".

The main use of "keep" is to continue forward motion on the same street[3]. When subjects used "keep" at forks, it was always to select the straighter of the two alternatives. Verbs "stay" and "continue" were similar.

2.1.2 Direction

Verbs tell about the kind of motion. Other words tell the direction of the motion. In almost all cases, it is sufficient to say either "left" or "right". In some cases, there will be more than one street on the same side, and some other tactic is required.

One is to name a landmark that lies in that direction, e.g. "you bear to the left here and go under the bridge" or "straight to where those lights are.". This tactic can also be used when there is no ambiguity, and has the advantage that it also works for people who confuse left and right. In addition, combining a landmark with a direction name ("Go left towards the blinking lights.") adds redundancy to the instructions, thus making them easier to follow. Redundancy is a feature worth incorporating in the Back Seat Driver.

Other approaches to ambiguity are less successful. One subject tried to specify the street using "clock face" terms, where 12 o'clock is straight ahead, 3 o'clock is right, and 9 o'clock is left: "bear to the left about ten o clock" but when this did not work, he simply pointed. Another ordered the streets by amount of turning: "Now here you want to bear left. *Not all the way left* but straight to where those lights are". Note that this specification of directions also uses a landmark.

[3]This surprised me. In my own speech it is synonymous with "bear".

2.2 Distance and Time

In addition to knowing what to do, the driver must know where (or when) to do it. Notably absent from the directions are units of distance. Subjects *could* have given instructions by saying "Drive 310 yards, then ...", but did not. When subjects did give distances, they used qualitative terms like "in a while", "up ahead", "soon", or "not too long after ...". This is not simply because subjects are ignorant of the distances. When I asked them how long we would remain on the current road, most answered with units of either miles or minutes, and the answers were reasonably accurate. Subjects did have some idea of distance, but instead chose other means to tell the driver when to act.

The most common strategy is to give the instruction **immediately** before the action, just early enough that the driver has time to slow down for the turn[4]. Instructions given immediately often include a reference to "here" or "right here" as the place to act.

I think that subjects use this form in part because they are not able to formulate the instruction until they are actually at the place of choice. In Benjamin Kuipers' model of navigation ([46, 47], and discussed in 8.5) the earliest form of route knowledge is a "felt path" where a route is a sequence of pairs of scene description and action. The navigator can not give the next instruction until actually at the place described. Suggestive evidence for this account is that some drivers broke up instructions into two parts, first telling how to get to the next choice point, and then giving the next instruction only when at the point, as shown in this excerpt from a transcription[5].

[4]This is an assumption, not a fact. I did not measure the relationship between vehicle speed, distance to the intersection, and the time when the passengers spoke. Nor do I have evidence that passengers could reliably estimate these quantities. The subjects had all driven for at least five years. It would be instructive to hear the instructions given by those who have never driven.

[5]The transcription conventions are explained at length below. Briefly, punctuation represents features of spoken delivery, not grammatical form, so sentences do not generally end with periods.

> Just keep going until () I think it's until the next major intersection
> at least it's the next light anyway
> Take a left at the light

Further evidence is that subjects sometimes changed their instructions when approaching the intersection:

> Now we're gonna pass Harvard Ave and it's gonna be the next (no)
> maybe we're gonna turn onto Harvard Ave come to think of it gonna
> turn right () on Harvard

To make sense of this, assume that people are giving instructions according to a deficient mental map. When they see the actual intersection, they are able to recall the correct instructions.

Subjects who do have an accurate mental map can give the instruction at the earliest moment when it is unambiguous, that is, when the turn is the next turn, no matter how far away it is. They can also count ahead, and express the distance in units of blocks, turns, or lights ("take the second right"). This gives the driver plenty of notice without requiring much extra work. But such a count can be ambiguous if some of the objects counted are uncertain instances of the category. A small alley or a blinking light might or might not be included in the count. Either for this reason, or lack of knowledge, subjects did not make much use of counting.

One place where it is useful to give distance by a measure is in going around rotaries. In the one case where a route included a rotary, the subject said "You're gonna go around three quarters of the way and head across the bridge". In a rotary, the only appropriate units are those of angular distance, since there may not be signs, and the exits come up quickly.

Second, the empty parenthesis "()" represents a brief pause.

2.2.1 Landmarks

Subjects can tell the driver when to act by naming a landmark at the place of action. Perhaps the best example of use of landmarks is in an instruction for the turn from Massachusetts Avenue onto Back Street, just after crossing the Harvard Bridge into Back Bay, Boston:

> At the very end of the bridge here there's um a v- hard right which is h- very hard to see uh you want to take it umm it's like right beyond one of those jersey barriers you want to go in there behind this building where this taxi is coming out

This instruction includes four separate descriptions of the *position* of the street ("end of the bridge", "beyond the barriers", "behind this building", and "where this taxi is"); a description of the relative angle of the turn ("hard right") and a description of the street itself ("hard to see"), which may also warn the driver to devote extra effort to finding it[6]. It is not clear why the subject mentioned the angle of the turn, since there is only one right turn at that place, unless it was either to warn the driver to go extra slowly (for the sharp turn) or because it is hard to see.

One commonly used landmark is the name of the street. Street names make up about one quarter of all landmarks. A street name is not a good clue for when to turn, because signs are hard to see, even in the day light, even when they are present and pointing in the right direction. Nevertheless, drivers do use them. A possible alternative reason for providing a name is to help the driver learn about the city.

Other, equally commonly used landmarks are traffic lights and stop signs.

[6]Note also the use of "very" and "right" to mean "immediate".

These are especially useful because the driver is actively looking for them anyway, simply from a desire to avoid accidents.

Notably absent are "famous" landmarks. It is possible to name directions with reference to features such as those named by Kevin Lynch[50] in his classic book *The Image of the City*. These features include widely visible landmarks, nodes (major concentrations of flow or activity), and districts (visually distinct areas within the city). Some subjects did name prominent cultural and geographical features along the route, but only as background, not to tell me when to turn. The landmarks that people did use are what Lynch calls "local landmarks", having meaning only in an immediate context.

2.2.2 Advance Notice

Instructions for an act can be given more than once. One subject gave instructions twice, first in a general form well in advance of the action ("So we're gonna be following Commonwealth for a while and in maybe a mile it bears off to the left and we'll follow it to the left.") and then again at the time of execution: ("it bears left here").

Advance instructions may refer to the same landmark more than once. The way that people talk about a landmark depends upon its proximity. Subjects indicate the distance to a landmark implicitly by how they refer to it. While approaching an intersection, the landmarks may not be visible (in this case, the traffic lights are around a curve).

> There's a set of lights right up here (gonna go) straight through them and bear to the right

The subject uses an indefinite article since the objects are not visible. (Note also that two instructions are combined into one utterance.) After going straight

through the lights, the next landmarks are now visible in the distance:

Bear right at that gas station and blinking lights

The subject uses a distal deictic ("that"). Later, when close to the lights, he used a proximal deictic ("these"):

at these flashing lights you'll bear right

2.3 Advice

Cooperative subjects give extra information to make following the route faster and safer. Lane advice tells the driver which lane to drive in, when driving on a road with more than one lane. Lane advice can be expressed as positive ("get in the left lane" or "stay in the left lane") to prepare for a turn which can only be made from the selected lane, or as a negative ("make sure you don't get caught too firmly in the left lane") to avoid a lane blocked by traffic waiting to turn or by parked cars, or reserved for turns.

Other advice includes warnings about speed traps (clearly a service that the Back Seat Driver should also provide) and about foolish pedestrians (desirable, but difficult to automate). Other advice is possible. For a discussion of advice about traffic conditions, see chapter 7.

2.4 Style and Packaging

The information that navigators supply includes instructions, advice, and orientation. Above these three kinds of information is a level of **style**.

People gave instructions in several different ways. Most used simple imperative sentences ("Take a right", "Keep going") while a few used future tense, either second person ("You're gonna take a right") or first plural ("We're gonna turn right"). Still others used an indirect style, talking about the driver's "wants" ("You're gonna wanna take a right"). I think this style is more polite, by speaking as if the goal of getting some place belonged to the driver, not the instruction giver, that is, it's not that the instruction giver is giving orders so as to get to her destination, it's that the instruction giver is providing the driver with information that the driver needs. This style was often combined with a description of the road ("The road forks up ahead."), which justified the choice.

Subjects were fairly consistent in style, but I have no idea why they preferred one form to another. I believe that stylistic choices have more to do with interpersonal relations than with the essentials of direction giving, and interpersonal factors are not accessible through the method of investigation employed in this study. It is essential to this method that people complain about what they dislike. People will complain if instructions are wrong, or even unclear, but they might not complain if they dislike the interpersonal message they think they are getting. (Communication on that level is rarely explicit.) Moreover, I do not believe that my subjects took the computer as a "person", so there were no interpersonal factors. In the section on "mistakes" I describe one way that the Back Seat Driver tries to adopt a gentle style with drivers.

2.5 Silence

We should also consider what is *not* said. At most intersections the driver has a choice of directions, yet we do not find subjects giving instructions at every intersection. This can only mean that subjects assumed that there was a unique choice that was obvious, and that this choice was also obvious to the driver. This

follows from H. P. Grice's maxim of QUANTITY[28]: "Do not make your contribution more informative than is required." Cooperative speakers speak only when required. If a subject is silent, the thing to do must be obvious. Unfortunately, the inverse is not true. That a subject spoke is not evidence that the action described was not obvious. Some subjects give explicit instructions at places where there is no choice whatsoever for example, on one-way streets. Speaking might also serve to reassure the driver of the subject's attention and competence. When we find some subjects speaking, where others are silent, we can guess that the act was not wholly obvious, but we cannot be sure.

The obvious thing is usually to stay on the same road. This may be less obvious when staying on the road requires crossing a bigger road, since subjects sometimes spoke in this situation ("Go straight through the lights"). This follows from the usual pattern for cross-town routes: to go from local streets to progressively larger streets (collectors, then arterials), and then back again to small streets when near the destination. Subjects might want to override a presumption of turning onto the first collector encountered.

At some forks, one branch is the obvious next branch. An example is the connection between Memorial Drive, Brookline Street, and the Boston University Bridge. The right branch (going either up or down the Charles River) leads to a rotary from which one may turn onto Brookline Street or the bridge. The left branch leads up and over the rotary. Most (not all) of those whose routes stayed on Memorial Drive passed through this fork without comment. The left branch is the obvious place to go because it has two lanes and is more straight. An example of a fork without an obvious branch is the connection between Memorial Drive and Massachusetts Avenue, near MIT. Here the left branch leads underneath Massachusetts Avenue, and the right branch forces a turn. Even though the left branch is wider than the right, it is not obvious, perhaps because it departs at a steeper angle than the right branch does. Subjects always were explicit about

which branch to take.

2.6 Example Instructions

Here is one of the transcriptions, and a map showing the route. I have adapted the notation system of Gail Jefferson [72]. This notation system is specialized for study of interaction between speakers. Words are spelled the way they sound, not the way they would be written, so, e.g. "going to" is written as "gonna", when so pronounced. The notation is explained in table 2.2. I have chosen to capitalize proper nouns to make the account easier to read.

symbol	meaning
curly braces	indicate location
-	hesitation or cut-off speech
L:	the driver is speaking
R:	the passenger is speaking
()	an untimed pause
single parenthesis	enclose uncertain words
double parenthesis	vocal style or non-vocal sound
left bracket	marks simultaneous speech
colon	marks extended length syllable

Table 2.2: Notation system for transcriptions

This route goes from the parking garage at 12 Albany Street, Cambridge, to a garage at Glenville Terrace in Allston.

```
    {at 12 Albany}
1 R: and at the stop sign take a right on Main
      {on Main Street}
2 R: and you'll keep going straight
3 R: this is Tech Square
4 L: mhhmm
5 R: MIT AI Lab is to your left and behind you
```

6 L: hmm
7 R: so keep going straight past Ames Street
8 R: dont hit the pedestrians
9 L: ((in silly voice)) We want to die::
10 R: (keep) going straight
11 R: merge here I believe with Broadway
12 Go straight at the stop sign
13 and then you're going to take a right on Memorial
14 (at the) sign that says Memorial Drive West
{on Memorial}
15 you can see uh that you're driving right along the river and
16 Boston is on the other side on the left
17 L: mhmm
18 L: what part of Cambridge are we in
19 R: we're in Kendall Square () area ()
20 and basically we're passing by the uh passing by MIT the long way
21 much of it is right on Memorial Drive
22 L: mhmm
23 L: how long will I be on this street
24 R: oh about another () mile mile and a half
25 L: ((unclear))
{approaching Massachusetts Avenue fork}
26 R: you bear to the left here and go under the bridge
27 under the overpass I guess
28 L: uhhuh
((noise of tires on pavement))
29 R: down the ways a bit we're gonna cross over the river to our left
30 umm cross a bridge called the B U Bridge
31 but you have to bear off to the right and circle around

32 R: you're gonna want to get into your right lane
33 R: and you're gonna bear off () to the right here ()
34 where it says route 2 ()
35 and this is a traffic circle
36 you're gonna go around three quarters of the way
37 and head across the bridge
38 R: stay in the right lane here cause you're gonna take a right
39 L: uh huh
40 R: so we're leaving Cambridge and going into Boston now
41 and uh Boston University is right around here
42 right along the river
43 L: mhmm
44 R: and we'll be driving past () some of BUs buildings
45 R: you're gonna take the first right here on Commonwealth () Ave
46 R: so we're gonna be following Commonwealth () for a while
47 an:d in maybe a mile it bears off to the left
48 and we'll we'll follow it to the left
{Commonwealth and Babcock}
49 R: might need to get into the left lane for this uh bearing left
50 ()
51 in fact it bears left here
52 ()
53 middle or left lane
54 R: So I guess a good thing to remember for the directions here
55 is you follow the Green line around (when) you bear left
56 R: now we're gonna pass Harvard Ave
57 and its gonna be the next
58 (no) maybe we're gonna turn onto Harvard Ave
59 come to think of it

60 gonna turn right () on Harvard
61 an:d that it be coming up right here?
62 yes its the first right then after you bear left
{Commonwealth and Harvard 6:01}
63 R: okay now we're gonna turn right on the first street
64 which I believe is (glenough)
65 and this is our destination ()
66 towards the end of the street
67 L: here's Glenville on the left
[
68 R: Glen- Glenville
69 L: This street here?
70 R: yes
71 L: Glenville Terrace
72 R: Glenville Terrace

the Boston DIME file required reexamining the entire area in person. For the most part, this required no more than an hour for each square mile. More time was required for complicated intersections which had the kind of anonymous roads so poorly surveyed in the DIME maps. To enter these, I would make a sketch map on the spot, then enter the changes using a graphical editor. This allowed for reasonably quick data entry, but was not very accurate, since I used only my eyes to measure distance and angle.

I had edited much of the map earlier for Direction Assistance, but I also found that the Back Seat Driver requires more accuracy than Direction Assistance because the Back Seat Driver needs accurate positions to deliver messages at the right time. Also, people following written directions (as in Direction Assistance) rely more on their own intelligence to figure out when to act. If there is a discrepancy between the instructions and the world, they look around to try to understand it and correct it. But users of the Back Seat Driver just do what the machine tells them to do.

3.5 Other maps

Those who have built other automotive navigation systems have also found it necessary to add features to their maps. Here I describe features beyond those present in DIME.

Neukircher [58] describes the features of the map used in the EVA system. This map has better position information than DIME. Points are stored in three dimensions and are accurate to 2.5 meters. Road segments are straight lines, chosen so that a new segment begins at either an intersection or when the change in direction exceeds 30 degrees, or when the distance from the center line exceeds 5 meters. Additional attributes of the roads include height and weight restrictions,

location of magnetic anomalies, warnings, landmarks, special objects useful in descriptions (e.g. underpasses), layout of complex intersections, and signs. The map has two levels of detail[65]. The coarse level is used for route finding, and the fine level has more detailed information for position finding. Route finding information includes *two* values for expected speed (one for normal conditions and a second for times of high density), the expected wait time at segment endpoints, and areas where children are likely to be playing.

The University of Calgary AVL-2000 system uses a map that originated as a Canadian government Area Master File. This format, similar to DIME, also required extensive augmentation[33]. Link (segment) attributes include distance, expected travel time, safety, scenic value, tolls, "impedience value" [sic], one way limitations, banned turns, road type (over- and under-pass, traffic circles, clover leaf), presence of meridians (divided?), and restricted areas. Harris describes as a "special problem" those "source or destination points which correspond to a street addresses [sic] which do not have a unique node identifier". Either their map representation cannot interpolate addresses along segments, or the route finder is restricted to finding routes to nodes only. Harris also mentions auxiliary road information including landmarks, points of interest, emergency services, commercial establishments, weather conditions, traffic flow, and road characteristics, and stresses the importance of being able to update the map database over a communications link while driving.

Most systems have expanded the classification of streets. The ETAK map classification is:

- Interstate highway
- Semi-limited Access Roads and State Highways
- Arterial
- Collector

- **Light Duty Roads**
- **Alleys or Unpaved Roads**
- **High Speed Ramps**
- **Low Speed Ramps**

This is a richer taxonomy than that of the Back Seat Driver, and is essential to ETAK because of its significance in choosing which roads to display (lesser roads are suppressed at larger scales to control detail) and in which colors to display them. The Back Seat Driver could also benefit from such a taxonomy. The EVA system has a two level taxonomy:

- rural
  - motorways and federal highways with separate directional lanes and without intersections
  - federal highways
  - roads wider than six meters
  - roads four to six meters wide
  - others
- urban
  - divided
  - through
  - main
  - side
  - restricted

These maps have some questionable design decisions on the representation of legal restrictions. The ETAK map has no legal topology at all. It is not intended for route finding. The EVA map apparently encodes restrictions on turning by signs, rather than directly in the network. The Calgary map represents legal topology (one ways, banned turns) as a link attribute instead of in the network

topology. It may be that the street network represents only physical topology, with the assumption that legal topology will be equivalent to physical topology unless specially indicated. The Back Seat Driver appears to be unique in maintaining separate but equal representations for physical and legal topology. These two topologies should be integrated because legal topology is needed for route finding, and physical topology for route description.

Some other navigation systems attempt to give warnings about hazardous conditions. In those systems (EVA, Calgary) the hazards (about slope, width, or curves) are encoded explicitly into the map. It is unclear how "safety" (in the Calgary map) is represented, or whether it *should* be explicitly represented. A system which can compute safety from other attributes (traffic flow, slope, width) will be more general than one which relies on stored data. On the other hand, if safety is based on external information (accident statistics) then it belongs in the database.

3.6 Improvements are still needed

The Back Seat Driver's map, advanced as it is, could still be extended. Both route finder and descriptions would benefit from a more powerful map database. Desirable enhancements include:

- **Time dependent legal connectivity.** Sometimes a given turn will be prohibited only at certain hours of the day, typically rush hour. At present, Back Seat Driver must record such turns as always prohibited. This results in less than optimal routes. In Cambridge, Memorial Drive is closed on Sundays during the summer to create a large play space. The Back Seat Driver map representation has no way to record such arbitrary, yet predictable changes. In general, the Back Seat Driver needs the ability to change legal connectivity

Chapter 7

Related Work

This chapter first surveys related work on computer programs which provide navigation assistance to drivers, then develops a taxonomy of such systems. A related survey can be found in [56].

7.1 Early Work

Early application of computers to navigation was intended to reduce traffic congestion by providing route information to drivers. The designers of the Electronic Route Guidance System (ERGS) intended to make traffic flow more efficient by balancing load. They believed that reducing driver uncertainty at decision points would make traffic flow faster and more safely. In the ERGS design, a driver beginning a route finds the intersection closest to the destination, then enters a five letter code word for the intersection. When the vehicle passes over an induction loop sensor in the road it transmits the destination to a central computer. The computer determines the best route, and relays instructions to the car. This

interchange of information occurs at every instrumented intersection. Driving directions combine simple text from a nine word vocabulary and directional arrows, and are displayed by a "heads-up" display. The ERGS system was designed but never implemented[70]. A similar system was designed and tested in Germany in the late seventies[14].

7.2 Elliot and Lesk

The pioneering work on computer navigation assistance is by Elliot and Lesk[21, 22]. They showed that general purpose graph search algorithms[1] are not suited to the problem of finding useful routes for people traveling in the real world. There are two reasons why this is so. First, general purpose graph search algorithms are complicated because they must work with any kind of abstract graph, but street maps are among the simpler forms of abstract graphs. The extra complexity in an algorithm for arbitrary general graphs makes it slower than one which is specialized for searching simpler graphs.

A second problem with general search algorithms is that the shortest route may not be the *best* route. It might be a maze of shortcuts. Elliot and Lesk say that people who saw such routes "recoiled in horror", and so they modified their algorithm to prefer a route which was slightly longer but had fewer turns. The usual algorithms for graph search consider only the cost of traveling along an arc

[1]Abstract graphs are the mathematical basis behind all computer route finding. An abstract graph is a set of **nodes** (points) and **arcs** (lines joining two nodes). To represent a street map as a graph, think of intersections as nodes, and streets as arcs. If two intersections are directly connected there will be an arc between the corresponding nodes. A route between two nodes is a chain of arcs, each leading from one node to the next, such that the origin node is the first node, and the destination is the last node. Each arc may have an associated cost (greater than zero) which represents the effort required to travel the associated street. Usually this would be the length of the street, but it might also represent the toll collected on a turnpike. If the cost is the distance, then the shortest route is the route the sum of whose arcs is least. Finding a route, or the shortest route, through a street map is a special case – and perhaps the best example – of the problem of searching an abstract graph.

(a street), and take the cost of going from arc to arc to be zero – that is, having arrived at a node, all arcs are equally accessible. But this is not true of street driving. It takes more time to make a left hand turn across oncoming traffic than it does to go straight, and it takes extra effort to locate the place to turn. Elliot and Lesk added a system of **weights**, which are extra costs associated with turns. To their algorithm, the cost of a route was the sum of the distance along the streets and the difficulty of making the turns. They set the weight of a left turn to be 1/4 mile and a right turn to be 1/8 mile. This caused the algorithm to prefer slightly longer routes with fewer turns to short, twisty routes. Every known route finder trades distance for simplicity.

Elliot and Lesk also were the first to implement a program to generate natural language driving instructions for the route. This is not a straightforward translation. To understand why, you must understand that the map represents each street as a set of segments, where a segment is a piece of a street chosen to be short enough that it is a straight line and no intersection with any other segment occurs except at a segment endpoint. The route as represented by the route-finding algorithm is a sequence of street segments, not of streets. A street segment does not match any common sense notion of a road. Route descriptions must be expressed in terms of motion along streets (across many segments) and turns, not as a list of segments.

In their instructions, a route consists of a beginning, a sequence of turns and crossings (of rivers or railroads), and an ending. For each of these, there is a template to generate a sentence. A template is a sequence of words and slots, representing fixed and variable components of a sentence for a given type of act. The words are copied directly to the output, and the slots are filled in according to the particulars of an act. An example template is

```
Go <distance> [<intersections>] turn <direction> on <street>.
```

Here "Go", "turn", and "on" are the fixed words, and everything else is a slot. The slot `<intersections>` is optional. This template might produce:

```
Go 0.3 miles (2 intersections) turn left on TROY HILLS RD.
```

A third contribution of Elliot and Lesk was to integrate the digital map with other location oriented databases, including a Yellow Pages and a personal address book. This allowed the program to find routes to addresses given a person's name, to find the closest store of a specified category, and to mention stores along the route as possible landmarks.

7.3 Direction Assistance

Direction Assistance[19] provides spoken directions between locations in the Boston area. It uses a Dectalk speech synthesizer. This synthesizer includes a telephone interface, so it can answer a phone call and decode touch tone button presses. To use Direction Assistance, you call it from a touch tone phone. It answers the call, and prompts you to enter your origin and destination locations as street addresses. It finds a route, then describes the route to you. Direction Assistance was directly inspired by Elliot and Lesk, and extends their work in three ways.

The most significant difference is that Direction Assistance speaks its directions, where Elliot and Lesk drew maps and provided written text. Using speech makes the program much more accessible, since only a touch tone phone is required, rather than a computer terminal. The disadvantage is that users must remember the instructions or write them down.

7.3.1 Entering addresses

The method of address entry is of some interest. You enter an address by first entering the digits, then a number sign, then spelling the street name using the letters on the telephone keypad. The letters "Q" and "Z" are on the "6" and "9" keys, respectively, and the space character is on "1", which is otherwise unused. These keys are sufficient to spell any street name in Boston. (The spelling rules would require expansion to enter street names with other characters in them, for example "4th Street".)

Spelling a street name requires only one button push for each letter, even though there are three letters on each key. This is because of the redundancy in street names, which are pronounceable words, not arbitrary strings. There are 37 pairs of street names with the same "spelling" in the reduced "alphabet". An example is "Flint" and "Eliot", both encoded as "35468". This is only one percent of the (2628) names of streets in Boston, so collisions are rare. This technique appears workable even for larger sets of names. When the entire word list of the Brown corpus are encoded, there are still only 1095 collisions in the 19837 words (5.5%).

If a name collision occurs, the interface reads the list of possibilities, and asks the driver which one was meant. This is very rare. A more common problem is that street names are duplicated. For example, there are 14 possible meanings for "10 Washington":

```
10 Washington Avenue, East Boston
10 Washington Avenue, Union Square, Somerville
10 Washington Avenue, Chelsea
10 Washington Court, Central Square, Cambridge
10 Washington Place, South Boston
10 Washington Square, Charlestown
10 Washington Street, Charlestown
10 Washington Street, Central Square
```

```
10 Washington Street, North End, Boston
10 Washington Street, Union Square, Somerville
10 Washington Street, Brighton
10 Washington Street, Brookline
10 Washington Terrace, Union Square, Somerville
10 Washington Terrace, Charlestown
```

(This is the worst case example. There are only half as many possibilities for "100 Washington".) When this happens, the system asks the user a series of questions to reduce the list to a single choice. The system tries to ask the fewest questions possible. It asks the user to choose from a list of street types, if that is sufficient to resolve the question, and otherwise from a list of the containing cities (or neighborhoods, if there are two instances within a single city). To select from a list, the system reads the contents, asking the user to push a button when the desired choice is read. The interface is described more fully in [18].

A problem not addressed by Direction Assistance is that some "addresses" do not refer to streets at all, but rather are the names of buildings or developments, e.g. "11 Cambridge Center" or "One Kendall Square". Direction Assistance can only understand addresses expressed in terms of named streets.

7.3.2 Generating text

A second significant difference between Direction Assistance and the work of Elliot and Lesk is that Direction Assistance generates better quality descriptions of the route. The improvement arises because the text generation process first analyzes the route into a sequence of "acts", and then generates descriptions from these acts, instead of working directly from the route. An act represents something that the driver does. There are eleven different acts, each representing a different way of moving. The type of act depends upon topology (how many streets are present at an intersection, and which way traffic can flow), geometry (what angles

the streets make) and what kind of streets are involved. Thus we say "bear right at the fork" rather than "turn right", but we don't say that in taking an exit from a highway we are "bearing right". An act may involve more than one segment, as for instance a "U Turn" on Memorial Drive (shown in figure 7-1) takes one from Memorial Drive, to Danforth, and back onto Memorial Drive, yet should not be described as two successive turns. For each act there is a specialized text generator

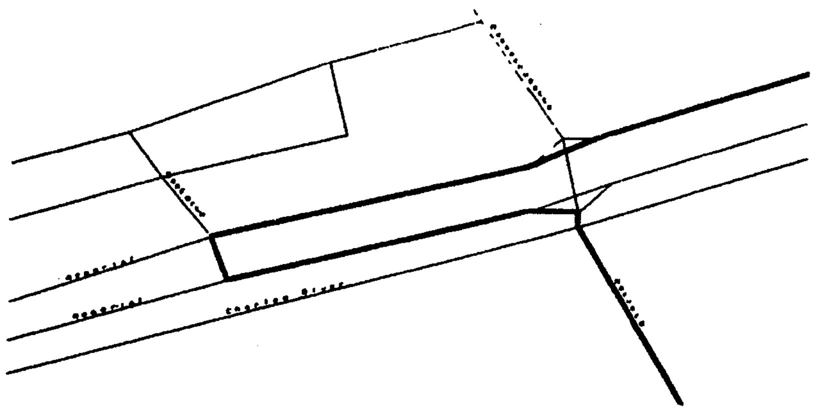

Figure 7-1: A U turn

to describe it. There is also a function to find an appropriate cue or landmark (e.g. a street crossed or an underpass) just before the location of the act.

7.3.3 Route Finding differences

The Direction Assistance route finder uses a different algorithm than Elliot and Lesk, and has a different set of weights. The algorithm is the A* search[35]. The weighting scheme ranks roads by a four-valued "goodness" feature and penalizes routes that use less good roads by multiplying the mileage by a constant factor. It also reduces or waives the penalty for turning under a set of circumstance having to do with predicted ease of following; for example, a turn onto a one way street incurs a lesser penalty, since it is unlikely that the driver would turn the wrong

way. It reduces the penalty for "T" turns since the driver can not possibly miss the place to turn. In practice, these weight changes have very little effect.

7.4 Text-Based Directions

7.4.1 Counter Top Directions

The Hertz car rental company offers "Computerized Driving Directions" at some of its rental counters. The directions include approximate mileage and estimated travel time, but are highly schematic, even cryptic. An example appears in figure 7-2. Despite appearances, these instructions are not computer generated.

```
APPROXIMATELY 16.8 MILES 0 :35 TIME
 2.0 MI NORTH  TO   I-78 WEST           enter LEFT
14.0 MI WEST   TO   NEW PRO/BERKELEY EXT bear RIGHT
                    DIAMOND HILL RD continue
 0.4 MI        TO   MOUNTAIN AVE turn RIGHT
 0.4 MI        TO   AT&T/BELL LABS on your right
```

Figure 7-2: example of driving instructions provided by Hertz

The Hertz system is more akin to a database retrieval system than a route finder. A California firm, Navigation Technology, sells a product called "DriverGuide" which is reported to be able to print driving directions between any two points[71, 4] in the San Francisco area.

7.4.2 Ma

Peeder Ma describes a system which gives textual directions in [51]. His work is similar to both Elliot and Lesk's and to Direction Assistance, but was apparently created independently of both. Ma uses A* search with a penalty factor to

minimize the number of turns. Unlike Elliot and Lesk, he uses the same penalty for both left and right turns. His street map representation does not include one-way streets or restrictions on turning ("no left turn") so it does not always find usable routes. His route descriptions use a taxonomy about as elaborate as that of Direction Assistance, but the text generated is more stylized.

7.5 Automotive Navigation Systems

Several groups have built position or navigation systems for use in automobiles. For the most part, these systems have not been well described in the literature, probably from a desire to preserve commercial secrecy.

The most well known in the United States is the ETAK Navigator, which displays the car's position on a map display on the dashboard[36, 89]. The map rotates as the car turns so that the forward direction is always straight up on the map. The ETAK Navigator can show the map at four different scales. At greater scales, the display shows only large streets in a straightened form. This is important to keep the map legible at large scales. The system provides a limited amount of navigation assistance. The driver may enter a destination (as a street address or intersection), and the system will display the direction and distance to the point. It remains the driver's task to select an appropriate route to the destination.

The Routerechner provided directions in and between German cities [30]. The route finder could receive real time traffic information by digital radio while on route. This system's map included only the Autobahn, and not the cities (this was before CDROMs were widely available), yet it was also provided a limited navigation service within cities. The user entered the destination as a pair of coordinates, and the system displayed the direction and distance to the destination. As with

ETAK, it was the user's responsibility to select an appropriate road. Haeussermann reports that users were always successful at finding their destinations and were pleased with the system.

The Honda Electro Gyro Cator[83] provided displayed position of the car by plotting a point on a screen. The driver could determine position by placing a transparent map over the screen. This system did not provide route directions.

The Nissan-Hitachi car navigation[38] and information system displays position on a map, finds the shortest route to a destination taking into account real time traffic information, and gives directions by arrows on the face of a display. The system also includes a "secretary mode" which displays the driver's appointments. The system uses a CDROM for map data, and combines satellite positioning with dead reckoning.

The EVA[65, 58](Automatic Navigation System) developed in Germany by Blaupunkt, the University of Karlsruhe, and the federal government, accepts destinations as street addresses, finds minimum time routes, and gives directions by a combination of simple (arrow) graphics and voice. The system can recover from a driver error in following the route and find a new route within 50 meters of travel.

The Phillips corporation, in the Netherlands, is developing a prototype car information and navigation system called CARIN[85, 8]. The driver enters a destination using either a keyboard or a touch sensitive screen. The system displays routes on a map and gives spoken driving instructions. The map is stored on board in CDROM, and a radio link provides for updates on traffic conditions. The system is potentially interesting, but very little has been published about it.

7.6 Classifying navigation systems

Navigation systems can be classified along three dimensions. There are three

kinds of navigation service:

- **positional** systems tell you where you are.
- **orienting** systems show the direction of your destination.
- **instructional** systems tell you what to do.

A navigation system can provide one, two, or all of these services. Navigation systems can be further distinguished by how they provide the information:

- **verbal** systems speak.
- **text** systems provide text.
- **graphic** systems provide pictures.

Finally, systems can be classified as either **real time** or **static.** The categories of this classification are not independent. There can be no static positioning system, since one can not predict the future position of the car.

The systems of Elliot and Lesk, Ma, and Hertz provide static, text instructions. Direction Assistance gives static verbal instructions. There are several problems with "static directional" navigation systems. First, they do nothing to help the driver follow the route. The driver must determine for herself when to apply each instruction. Instructions like "drive half a mile, then turn left onto Maple Street" are no use if the driver is unable to measure mileage or can not determine the name of the street. The urban street network contains many short connecting roads (access ramps) which are nameless. Finally, even a named street might be missing its sign. In addition, the driver must keep track of which instruction is next. A second problem is that since the instructions must be specified in advance, there is little to be done if the driver does not follow the instructions, which might happen from error, or because the instructions are wrong, or simply ill-advised (as

when confronting a traffic jam). The simulated navigation system constructed by Streeter included instructions of the form "If you see this you've gone too far" but none of the actually implemented system did this.

Most systems which provide positions also provide orientation. (The Honda Gyro-cater provided position only, and the Routerechner provided orientation only.) Positional or orientational systems can be useful for navigation provided one can read a map and find one's own route. It is not clear whether the CARIN system retains a map as a "vestigial" display, or because its makers do not appreciate the superiority of speech, or because they see a need for positional information other than route finding.

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EXHIBIT 9

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF MASSACHUSETTS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Plaintiff, v. HARMAN INTERNATIONAL INDUSTRIES, INCORPORATED, Defendant.	Civil Action No.: 05-10990 DPW HIGHLY CONFIDENTIAL PURSUANT TO PROTECTIVE ORDER

<u>EXPERT REPORT OF BARBARA J. GROSZ, PH.D.</u>

22. I understand MIT's definition of the term discourse model to be:

> a way to provide information needed by a conversation participant in context to enable the conversation participant to determine why an utterance was provided and what the utterance means.

23. MIT's description of a discourse model represents the perspective of the "hearer" conversation participant. A discourse model also encompasses the "speaker" or "generating" conversation participant. A discourse model provides contextual information and the discourse state to enable the speaker to know what to say and how to express it.

24. In my opinion, MIT's proposed definitions for discourse generator and discourse model are fair and reasonable. This is based on my reading of the patent, the file history and my knowledge in the area of discourse and discourse theory. In particular, MIT's proposed definition of discourse model is consistent with an article I co-authored in 1986 about discourse structure with Candace Sidner and an article by Julia Hirshberg and Janet Pierrehumbert also cited in the patent. The paper Dr. Sidner and I co-authored is generally taken to be a classic in the field. In the article, we outline how the three constituents of discourse structure – attentional state, intentional structure and linguistic structure – supply information to participants in the conversation to enable the participants to generate utterances appropriate in context and understand what was said and why it was said. This particular article was referred to in the '685 patent specification and was incorporated by reference into the specification.

EXHIBIT 10

UNITED STATES DISTRICT COURT
DISTRICT OF MASSACHUSETTS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Plaintiff, v. HARMAN INTERNATIONAL INDUSTRIES, INCORPORATED, Defendant.	)	Civil Action No. 05-10990-DPW

Expert Report of Dr. Diane J. Litman

possessed a Bachelors Degree or higher in computer technology, physics, engineering, cartography, mathematics or related technical fields." EXPERT REPORT OF ROBERT FRENCH at pp. 3–4.

19. Neither MIT's nor Harman's person of ordinary skill in the art would necessarily have specialized knowledge of discourse, discourse generation or discourse models, or any advanced understanding of computational linguistics theory.

B. Dr. Grosz's opinion that "MIT's proposed definitions for discourse generator and discourse model are fair and reasonable" and Dr. Grosz's adoption of MIT's proposed definitions is based upon specialized knowledge in the field of computational linguistics that discounts the broader understanding of the term "discourse" and the prior art navigation systems that generate discourse.

20. I understand that one element of claim 1 of the '685 patent is

> ...a discourse generator functionally connected to said computing apparatus for accepting the current position from said location system and the route from said route finder, for consulting said map database, and for composing discourse including instructions and other messages for directing the driver to the destination form the current position.

21. I have reviewed both MIT's proposed definitions for the "discourse generator" claim element and the term "discourse model." I have also reviewed Dr. Grosz's adoption of MIT's proposed definitions. MIT's proposed definitions and Dr. Grosz's adoption of them incorporate current theories in the specialized area of computational linguistics, one example being the methods found in Grosz's work.

22. The term "discourse" can be defined as simply text or speech consisting of more than one sentence or utterance, respectively. *See* U.S. Patent No. 5,177,685 (filed August 9, 1990) at Claim 1 (". . .discourse including instructions and other messages"); *see also* THE RANDOM HOUSE DICTIONARY OF THE ENGLISH LANGUAGE 563 (2d ed. 1987) ("Any unit of connected speech or writing longer than a sentence") (linguistics definition); WEBSTER'S THIRD NEW

INTERNATIONAL DICTIONARY 647 (2002) ("connected speech or writing consisting of more than one sentence") (linguistics definition); THE OXFORD ENGLISH DICTIONARY 751 (2d ed. 1989) ("text or utterances longer than one sentence") (linguistics definition); DANIEL JURAFSKY & JAMES H. MARTIN, SPEECH AND LANGUAGE PROCESSING 669 (Prentice-Hall 2000) ("collocated, related groups of sentences"). In a coherent discourse, sentences/utterances are co-related, while in an incoherent discourse they sometimes are not. *See* JURAFSKY & MARTIN, *supra*, at 712 ("Discourses are not arbitrary collections of sentences; they must be *coherent*. Collections of well-formed and individually interpretable sentences often form incoherent discourses when juxtaposed.") In addition, the relation between the sentences does not necessarily have to be explicit. A group of sentences can be related simply by all talking about the same thing (*i.e.*, how to get from A to B). Furthermore, the definition of the concept of discourse can be understood without any reference to a discourse model.

23. A "discourse generator" can simply be something (either a program or a person, and is consistent with the '685 patent at Col. 23 Ln. 16) that creates a multi-sentenial text that is intended to be read or, in the case of Claim 1, provided as audio. Also, while it may be implied that discourse generation embodies the dynamic, and perhaps incremental creation of discourse, this is not required. Discourse can be generated outside of real-time, or can be generated by simply taking pre-recorded phrases or chunks of possible discourse and arranging them to be a coherent discourse.

24. Claim 1 of the '685 patent says that "discourse" is something that includes "instructions and other messages for directing the driver to the destination from the current position." The language of Claim 1 does not include any additional specifics about the type of discourse that

EXHIBIT 11

Computational and Conversational Discourse

Burning Issues – An Interdisciplinary Account

Edited by

Eduard H. Hovy

Information Sciences Institute, University of Southern California
4676 Admiralty Way, Marina del Rey, California 90292-6695, USA

Donia R. Scott

Information Technology Research Institute, University of Brighton
Lewes Road, Brighton BN2 4NT, UK

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Chapter 7
Empirical Analysis of Three Dimensions of Spoken Discourse: Segmentation, Coherence, and Linguistic Devices

Rebecca J. Passonneau[1] and Diane J. Litman[2]

[1] Columbia University, New York

[2] AT&T Bell Laboratories, Murray Hill

1. Discourse Segmentation

A discourse consists not simply of a linear sequence of utterances,[1] but of meaningful semantic or pragmatic relations among utterances. Each utterance of a discourse either bears a relation to a preceding utterance or constitutes the onset of a new unit of meaning or action that subsequent utterances may add to. The need to model the relation between such units and linguistic features of utterances is almost universally acknowledged in the literature on discourse. For example, previous work argues for an interdependence between particular cue words and phrases such as anyway, and their location relative to an utterance or text, (e.g., Hirschberg and Litman 1993, Grosz and Sidner 1986, Reichman 1985, Cohen 1984); the distribution and duration of pauses relative to multi-utterance units (e.g., Grosz and Hirschberg 1992, Hirschberg and Grosz 1992, Chafe 1980, Butterworth 1980); and the interdependence between the form of discourse anaphoric noun phrases and the relation of the current utterance to a hierarchical model of utterance actions, or to a model of focus of attention (e.g., Grosz 1977, Grosz and Sidner 1986, Reichman 1985, Sidner 1979, Passonneau 1985). However, there are a variety of distinct proposals regarding how to model the interdependence among the three dimensions of: 1. sequences of semantically and pragmatically related utterances, 2. the units or relations they reflect, and 3. lexico-grammatical or prosodic features. We refer to these dimensions respectively as segmentation, coherence, and linguistic devices. For purposes of this paper we have deliberately avoided adopting a particular theoretical framework in order to pose open-ended questions that we address through an empirical investigation.

Figure 1 presents an excerpt from a transcription of a spoken narrative taken from the Pear stories corpus (Chafe 1980) that we use in our study. We use the excerpt to illustrate the interdependence of segmentation, linguistic devices, and

---

[1] We use the term *utterance* to mean a use of a sentence or other linguistic unit, whether in text or in spoken language.

entities in 8.4, thus failing the first two tests. The third person pronoun *he* evokes an entity, the farmer, that was last mentioned in 3.3, and 1 NP boundary has been assigned since then, thus failing the third test.

Cue Words

Cue words (e.g., *now*) are words that are sometimes used to explicitly signal the structure of a discourse. Our segmentation algorithm based on cue words uses a simplification of one of the features shown by Hirschberg and Litman (1993) to identify discourse usages of cue words. Hirschberg and Litman examine a large set of cue words proposed in the literature and show that certain prosodic and structural features, including a position of first in prosodic phrase, are highly correlated with the discourse uses of these words. The input to our cue word algorithm is a sequential list of the prosodic phrases constituting a given narrative. The output is a set of boundaries B, represented as ordered pairs of adjacent phrases (P_n,P_{n+1}), such that the first item in P_{n+1} is a member of the set of cue words summarized in Hirschberg and Litman (1993). That is, if a cue word occurs at the beginning of a prosodic phrase, the usage is assumed to be discourse and thus the phrase is taken to be the beginning of a new segment. Figure 3 shows 2 boundaries (CUE) assigned by the algorithm, both due to *and*. Because *and* occurs frequently in phrase initial position, the cue algorithm assigns boundaries at a high rate. As noted below, this results in low precision.

Pauses

Grosz and Hirschberg (Grosz and Hirschberg 1992, Hirschberg and Grosz 1992) found that in a corpus of recordings of Associated Press news texts, phrases beginning discourse segments are correlated with duration of preceding pauses, while phrases ending discourse segments are correlated with subsequent pauses. We use a simplification of these results in our algorithm for identifying boundaries in our corpus using pauses. The input to our pause segmentation algorithm is a sequential list of all prosodic phrases constituting a given narrative, with pauses (and their durations) noted. The output is a set of boundaries B, represented as ordered pairs of adjacent phrases (P_n,P_{n+1}), such that there is a pause between P_n and P_{n+1}. Unlike Grosz and Hirschberg, we do not currently take phrase duration into account. In addition, since our segmentation task is not hierarchical, we do not note whether phrases begin, end, suspend, or resume segments. Figure 3 shows seven boundaries (PAUSE) assigned by the algorithm.

4.2 Performance of Algorithms

In this section we discuss the performance of the three algorithms first to evaluate their success at locating segment boundaries, but then to draw generalizations regarding the nature of segment boundaries. Unsurprisingly, the performance of

EXHIBIT 12

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Introduction

Articles

Book Review

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Discourse Segmentation by Human and Automated Means

Rebecca J. Passonneau*
Bellcore and Columbia University

Diane J. Litman†
AT&T Labs-Research

The need to model the relation between discourse structure and linguistic features of utterances is almost universally acknowledged in the literature on discourse. However, there is only weak consensus on what the units of discourse structure are, or the criteria for recognizing and generating them. We present quantitative results of a two-part study using a corpus of spontaneous, narrative monologues. The first part of our paper presents a method for empirically validating multiutterance units referred to as discourse segments. We report highly significant results of segmentations performed by naive subjects, where a commonsense notion of speaker intention is the segmentation criterion. In the second part of our study, data abstracted from the subjects' segmentations serve as a target for evaluating two sets of algorithms that use utterance features to perform segmentation. On the first algorithm set, we evaluate and compare the correlation of discourse segmentation with three types of linguistic cues (referential noun phrases, cue words, and pauses). We then develop a second set using two methods: error analysis and machine learning. Testing the new algorithms on a new data set shows that when multiple sources of linguistic knowledge are used concurrently, algorithm performance improves.

1. Introduction

Each utterance of a discourse contributes to the communicative import of preceding utterances, or constitutes the onset of a new unit of meaning or action that subsequent utterances may add to. The need to model the relation between the structure of such units (referred to here as **discourse segment structure**) and linguistic features of utterances[1] is almost universally acknowledged in the literature on discourse. However, natural language systems rarely exploit the relation between discourse segment structure and linguistic devices because there is very little data about how they constrain one another. We have been engaged in a two-part study addressing this gap. We report on a method for empirically validating discourse segments, and on our development and evaluation of algorithms to identify these segments from linguistic features of discourse. We show that human subjects can reliably perform discourse segmentation using speaker intention as a criterion. We also show that when multiple sources of linguistic knowledge are used (referential noun phrases, cue words, and pauses), algorithm performance approaches human performance.

The excerpt in Figure 1 illustrates the two aspects of discourse that our study addresses.[2] The first pertains to an abstract structure consisting of meaningful discourse segments and their interrelations. The utterances in segments X and Z of Fig-

* 445 South Street, Morristown, NJ 07960 (E-mail: beck@bellcore.com); Department of Computer Science, New York, NY 10027 (E-mail: becky@cs.columbia.edu)
† 600 Mountain Avenue, Murray Hill, NJ 07974 (E-mail: diane@research.att.com)
1 By the term utterance we mean the spoken or written use of a sentence or other linguistic unit.
2 This excerpt is taken from a corpus of spoken narratives (Chafe 1980) described below.

EXHIBIT 13

Davis
EXHIBIT NO. 74
2/16/06
M. D. O'CONNOR

A voice interface to a Direction giving program

James Raymond Davis

January 1987

Speech Research Group Technical Memo 2
The Media Laboratory
Massachusetts Institute of Technology

Finder needs to obtain two locations, and it does this by asking questions and soliciting input. The user can specify location by giving either a street number and name, or by giving a telephone number (the program's data base includes an inverted phone book). It needs to get several different types of input - answers to yes or no questions, telephone numbers, street numbers and names. It has little to say, other than to guide the user through the input process.

The Narrator, on the other hand, has a lot to say, and needs no input from the user. Its main concern is *flow control*, making sure that it is going as fast as the user can write, but no faster. Both of these modules also have the secondary goals of keeping the user oriented within the interaction and recovering from errors.

The initial message

Direction Assistance is designed to be used by people with no experience with computers or synthetic speech. Almost every American is at least familiar with the concept that computers might talk, but they are not experienced with interfaces built with present day technology. There are lots of ways to go wrong. The interface tries to forestall some of them with its initial message:

```
This is Direction Assistance.  I can speak to
you, but I can not hear your voice.  To tell me
anything, you must use the keypad on your
telephone.  If you get confused any time while
you're using me, hit the key with the star or
asterisk.
```

The initial message conveys two important ideas. First it tells users how to communicate. Until recently, people expected to use the telephone to talk with people. Nowadays, people are beginning to get used to having "conversations" with answering machines, which speak, and then listen. Very few people know how to interact with a program that speaks often, but listens only for button pushes.

The second idea is that there is always help available, and always in the same way, by hitting the "star" key. This is a surprisingly difficult concept to convey. Examination of the log shows that many of users never used the help key, and this was even true for people who daily used computer systems that had "Help" keys. There are several reasons this might be so. First, this initial message is unexpected, and may have caught people by surprise. Second, the message has no direct relevance to the task at hand, and people may have been too impatient to listen to it. Much of the testing was done with a much longer message (nearly one minute) and this surely taxed people's concentration. Finally, people may not have understood what "star" meant. It is hard to find names for the keys without numbers. Some people prefer "asterisk". The "number sign" key is even worse, being called "pound sign", "sharp sign", "hash" or even "tic tac toe" by different people.

Different types of input

There are four types of input Direction Assistance needs from the user: answers to yes or no *questions*, *selection* from a small list of items, *numbers*, and *names*. We now consider each in turn.

Yes or No

The interface poses a yes or no question by stating a possibility and requesting the user to hit any key if it is true, thus for example "If you want to enter a different address, please hit any key now." If the user takes no action within a specified time the answer is no. The wording of the message always includes the consequence of the "no" if it is not obvious. This protocol is easier to use than one that requires an explicit action for either "yes" or "no", but can be slower, since the user has to wait for the full duration allowed if the answer is no. This duration must be long enough for the user to make a decision.

Selection

Selection means choosing one of a small list of items. There are two types of selection. In a *sequential* selection the system slowly reads a list of choices, pausing briefly after each, until the user designates one by striking a key. This is effectively a yes or no question ("Do you want this one?") for each element of the list. In an *enumerated* selection the system reads the entire list, assigning each item a number, then asks the user to hit the key for the

number of the desired item. Each type of selection has its advantages and disadvantages.

Sequential selection is simple to use but can be very slow, since the user may have to listen to several undesired choices before hearing the one wanted. A second problem is that the user may not know which choice is the best without hearing them all. For this reason, if the user makes no selection, the selection routine offers to repeat the list.

Enumerated selection is harder to use than sequential selection because the user must remember and enter a number. The compensation for this complexity is that it can be faster than sequential selection. There are two reasons for this. First, the list is read faster, since the system need not pause to await a user action while reading. More importantly, if the user already knows the order of the options she can enter the number immediately, without waiting for the list to be read. An enumerated selection is appropriate when the same list of choices will be presented more than once.

Numbers

There are two types of numbers in this application, phone numbers and street address numbers. Phone numbers are entered in the familiar manner. The system simply collects the next seven button pushes. Street numbers require a delimiter, since the number of digits is not predictable. The delimiter is the number sign, since the only other key is the help key. Both phone numbers and street numbers require some additional checking, described below.

Names

The user selects street names by spelling them with the letters on the keypad. There are three reasons this is difficult: First, people are not familiar with the layout of the letters - they have to "hunt and peck" for letters. Second, the letters Q and Z, and the space character are missing. These are assigned to the 1 key, which bears no letters[2]

The third problem is that each of the keys has three different letters, and there is no obvious way for the user to designate which of the three is intended. Other systems have resolved this problem by using more than one button push per character, either with a shift sequence (e.g using keys *, 0, and # to select one of the letters.) or by hitting a key N times to select the N'th letter upon it. Direction Assistance is able to bypass this problem because the set of all street names in Boston is much smaller than the set of all digit sequences. A given digit sequence will almost always specify only one street name. If it does not (e.g. "MILL" and "MILK") the system asks the user to make a sequential selection among them. Witten [13] found 8% collisions in a 24,500 word dictionary when using this approach. In this application there are much smaller number of collisions, just eight out of 1000 names. This is both because of the smaller size of the set and because street names are longer than dictionary words. The mean length of a street name is seven characters.

Absence of Context is a problem

A telephone interface is harder to use than a graphics interface (such as a form filling environment or a menu) because there is no *context* present while the user is entering data. The interface always prompts for input, but the user may not understand the prompt because of noise, inarticulate speech, or inattention. Even if the prompt is correctly heard, it must also be remembered, for it is not present during the time the user is entering the data. In a graphics environment the prompt remains visible.

The problems, then, are that the user may not know what to enter or how to delimit it. Neither of these are explicitly indicated, other than in the prompt.[3] If a closing delimiter is expected, and none arrives after a fixed delay, a timeout occurs, and the interface reminds the user that a delimiter is required.

Handling Hangup

The interface is more complicated than it needs to be, because there is no way to detect whether the caller has

[2]In newer versions of the program, Q is on the 7 key, with PRS, and Z on the 9 key, with WXY.

[3]One possible solution is to employ acoustic icons, as discussed in [4]. The system might play a faint dial tone to indicate that phone number was expected, and ambient street noise to indicate that an address was expected.

EXHIBIT 14

Merriam-Webster's Collegiate® Dictionary

TENTH EDITION

®

A GENUINE MERRIAM-WEBSTER

The name *Webster* alone is no guarantee of excellence. It is used by a number of publishers and may serve mainly to mislead an unwary buyer.

Merriam-Webster™ is the name you should look for when you consider the purchase of dictionaries or other fine reference books. It carries the reputation of a company that has been publishing since 1831 and is your assurance of quality and authority.

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423—dc21 97-41846
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con·strain \kən-ˈstrān\ *vt* [ME, fr. MF *constraindre,* fr. L *constringere* to constrict, constrain, fr. *com-* + *stringere* to draw tight — more at STRAIN] (14c) **1 a :** to force by imposed stricture, restriction, or limitation **b :** to restrict the motion of (a mechanical body) to a particular mode **2 :** COMPRESS; *also* **:** to clasp tightly **3 :** to secure by or as if by bonds **:** CONFINE; *broadly* **:** LIMIT **4 :** to force or produce in an unnatural or strained manner ⟨a ~*ed* smile⟩ **5 :** to hold back by or as if by force ⟨~*ing* my mind not to wander from the task —Charles Dickens⟩ *syn* see FORCE — **con·strained·ly** \-ˈstrā-nəd-lē, -ˈstrānd-lē\ *adv*

con·straint \kən-ˈstrānt\ *n* [ME, fr. MF *constrainte,* fr. *constraindre*] (15c) **1 a :** the act of constraining **b :** the state of being checked, restricted, or compelled to avoid or perform some action ⟨the ~ and monotony of a monastic life —Matthew Arnold⟩ **c :** a constraining condition, agency, or force **:** CHECK ⟨put legal ~*s* on the board's activities⟩ **2 a :** repression of one's own feelings, behavior, or actions **b :** a sense of being constrained **:** EMBARRASSMENT

con·strict \kən-ˈstrikt\ *vb* [L *constrictus,* pp. of *constringere*] *vt* (1732) **1 a :** to make narrow or draw together **b :** COMPRESS, SQUEEZE ⟨~ a nerve⟩ **2 :** to stultify, stop, or cause to falter **:** INHIBIT **~** *vi* **:** to become constricted *syn* see CONTRACT — **con·stric·tive** \-ˈstrik-tiv\ *adj*

con·stric·tion \-ˈstrik-shən\ *n* (15c) **1 :** an act or product of constricting **2 :** the quality or state of being constricted **3 :** something that constricts

con·stric·tor \-ˈstrik-tər\ *n* (1735) **1 :** a muscle that contracts a cavity or orifice or compresses an organ **2 :** a snake (as a boa constrictor) that kills prey by compression in its coils **3 :** one that constricts

con·stringe \kən-ˈstrinj\ *vt* **con·stringed; con·string·ing** [L *constringere*] (1604) **1 :** to cause to shrink ⟨cold ~*s* the pores⟩ **2 :** CONSTRICT — **con·strin·gent** \-ˈstrin-jənt\ *adj*

[1]**con·struct** \kən-ˈstrəkt\ *vt* [L *constructus,* pp. of *construere,* fr. *com-* + *struere* to build — more at STRUCTURE] (1663) **1 :** to make or form by combining or arranging parts or elements **:** BUILD; *also* **:** CONTRIVE, DEVISE **2 :** to draw (a geometrical figure) with suitable instruments and under specified conditions **3 :** to set in logical order — **con·struct·ible** \-ˈstrək-tə-bəl\ *adj* — **con·struc·tor** \-tər\ *n*

[2]**con·struct** \ˈkän-ˌstrəkt\ *n* (1933) **1 :** something constructed by the mind: as **a :** a theoretical entity ⟨the deductive study of abstract ~*s* —Daniel J. Boorstin⟩ **b :** a working hypothesis or concept ⟨a point of view which made "abroad" singularly containable as a literary ~ —Jonathan Raban⟩ **c :** a product of mental invention ⟨the novel . . . a verbal ~ in which invented human characters appear —Anthony Burgess⟩ **2 :** something produced by human effort ⟨the East bloc was always an unnatural ~ —Walter Isaacson⟩

con·struc·tion \kən-ˈstrək-shən\ *n* (14c) **1 :** the act or result of construing, interpreting, or explaining **2 a :** the process, art, or manner of constructing something; *also* **:** a thing constructed **b :** the construction industry ⟨working in ~⟩ **3 :** the arrangement and connection of words or groups of words in a sentence **:** syntactical arrangement **4 :** a sculpture that is put together out of separate pieces of often disparate materials — **con·struc·tion·al** \-shnəl, -shə-nᵊl\ *adj* — **con·struc·tion·al·ly** *adv*

con·struc·tion·ist \-sh(ə-)nist\ *n* (1838) **:** one who construes a legal document (as the U.S. Constitution) in a specific way ⟨a strict ~⟩

construction paper *n* (ca. 1924) **:** a thick groundwood paper available in many colors and used esp. for school artwork

con·struc·tive \kən-ˈstrək-tiv\ *adj* (ca. 1680) **1 :** declared such by judicial construction or interpretation ⟨~ fraud⟩ **2 :** of or relating to construction or creation **3 :** promoting improvement or development ⟨~ criticism⟩ — **con·struc·tive·ly** *adv* — **con·struc·tive·ness** *n*

con·struc·tiv·ism \kən-ˈstrək-ti-ˌvi-zəm\ *n, often cap* (1925) **:** a nonobjective art movement originating in Russia and concerned with formal organization of planes and expression of volume in terms of modern industrial materials (as glass and plastic) — **con·struc·tiv·ist** \-vist\ *adj or n, often cap*

[1]**con·strue** \kən-ˈstrü\ *vb* **con·strued; con·stru·ing** [ME, fr. LL *construere,* fr. L, to construct] *vt* (14c) **1 :** to analyze the arrangement and connection of words in (a sentence or sentence part) **2 :** to understand or explain the sense or intention of usu. in a particular way or with respect to a given set of circumstances ⟨*construed* my actions as hostile⟩ **~** *vi* **:** to construe a sentence or sentence part esp. in connection with translating — **con·stru·able** \-ˈstrü-ə-bəl\ *adj*

[2]**con·strue** \ˈkän-ˌstrü\ *n* (1844) **:** an act or the result of construing esp. by piecemeal translation

con·sub·stan·tial \ˌkän(t)-səb-ˈstan(t)-shəl\ *adj* [LL *consubstantialis,* fr. L *com-* + *substantia* substance] (14c) **:** of the same substance

con·sub·stan·ti·a·tion \ˌkän(t)-səb-ˌstan(t)-shē-ˈā-shən\ *n* (1597) **:** the actual substantial presence and combination of the body and blood of Christ with the eucharistic bread and wine according to a teaching associated with Martin Luther — compare TRANSUBSTANTIATION

con·sue·tude \ˈkän(t)-swi-ˌtüd, kən-ˈsü-ə-, -ˌtyüd\ *n* [ME, fr. L *consuetudo* — more at CUSTOM] (14c) **:** social usage **:** CUSTOM — **con·sue·tu·di·nary** \ˌkän(t)-swi-ˈtü-də-ˌner-ē, kən-ˌsü-ə-, -ˈtyü-\ *adj*

con·sul \ˈkän(t)-səl\ *n* [ME, fr. L; perh. akin to L *consulere* to consult] (14c) **1 a :** either of two annually elected chief magistrates of the Roman republic **b :** one of three chief magistrates of the French republic from 1799 to 1804 **2 :** an official appointed by a government to reside in a foreign country to represent the commercial interests of citizens of the appointing country — **con·sul·ar** \-s(ə-)lər\ *adj* — **con·sul·ship** \-səl-ˌship\ *n*

con·sul·ate \-s(ə-)lət\ *n* (14c) **1 :** a government by consuls **2 :** the office, term of office, or jurisdiction of a consul **3 :** the residence or official premises of a consul

consulate general *n, pl* **consulates general** (1883) **:** the residence, office, or jurisdiction of a consul general

consul general *n, pl* **consuls general** (1753) **:** a consul of the first rank stationed in an important place or having jurisdiction in several places or over several consuls

[1]**con·sult** \kən-ˈsəlt\ *vb* [MF or L; MF *consulter,* fr. L *consultare,* freq. of *consulere* to deliberate, counsel, consult] *vt* (1527) **1 :** to have regard to **:** CONSIDER **2 a :** to ask the advice or opinion of ⟨~ a doctor⟩ **b :** to refer to ⟨~ a dictionary⟩ **~** *vi* **1 :** to consult an individual **2 :** to deliberate together **:** CONFER **3 :** to serve as a consultant — **con·sult·er** *n*

[2]**con·sult** \kən-ˈsəlt, ˈkän-ˌ\ *n* (1560) **:** CONSULTATION

con·sul·tan·cy \kən-ˈsəl-tᵊn(t)-sē\ *n, pl* **-cies** (1955) **1 :** CONSULTATI[ON] **2 :** an agency that provides consulting services **3 :** the position [of] consultant

con·sul·tant \kən-ˈsəl-tᵊnt\ *n* (1697) **1 :** one who consults another **2** **:** one who gives professional advice or services **:** EXPERT — **con[sul]·tant·ship** \-ˌship\ *n*

con·sul·ta·tion \ˌkän(t)-səl-ˈtā-shən\ *n* (15c) **1 :** COUNCIL, CONFERENCE; *specif* **:** a deliberation between physicians on a case or its tr[eat]ment **2 :** the act of consulting or conferring

con·sul·ta·tive \kən-ˈsəl-tə-tiv, ˈkän(t)-səl-ˌtā-tiv\ *adj* (1583) **:** of, re[lat]ing to, or intended for consultation **:** ADVISORY ⟨~ committee⟩

con·sult·ing \kən-ˈsəl-tiŋ\ *adj* (1801) **1 :** providing professional or [ex]pert advice ⟨a ~ architect⟩ **2 :** of or relating to consultation or a con[]sultant ⟨the ~ room of a psychiatrist⟩

con·sul·tive \kən-ˈsəl-tiv\ *adj* (1616) **:** CONSULTATIVE

con·sul·tor \kən-ˈsəl-tər\ *n* (1611) **:** one that consults or advises; *esp* [] adviser to a Roman Catholic bishop, provincial, or sacred congregat[ion]

[1]**con·sum·able** \kən-ˈsü-mə-bəl\ *adj* (1641) **:** capable of being consum[ed]

[2]**consumable** *n* (1802) **:** something (as food or fuel) that is consumabl[e] — usu. used in pl.

con·sume \kən-ˈsüm\ *vb* **con·sumed; con·sum·ing** [ME, fr. MF o[r] MF *consumer,* fr. L *consumere,* fr. *com-* + *sumere* to take up, take [fr.] *sub-* up + *emere* to take — more at SUB-, REDEEM] *vt* (14c) **1 :** to [do] away with completely **:** DESTROY ⟨fire *consumed* several buildings⟩ [2] **a :** to spend wastefully **:** SQUANDER **b :** USE UP ⟨writing *consum[ed]* much of his time⟩ **3 :** to eat or drink esp. in great quantity ⟨*consum[ed]* several kegs of beer⟩ **4 :** to engage fully **:** ENGROSS ⟨*consumed* w[ith] curiosity⟩ **~** *vi* **1 :** to waste or burn away **:** PERISH **2 :** to utilize eco[]nomic goods

con·sum·ed·ly \-ˈsü-məd-lē\ *adv* (1707) **:** as if consumed **:** EXCESSIVE[LY]

con·sum·er \kən-ˈsü-mər\ *n, often attrib* (15c) **:** one that consumes[:] **a :** one that utilizes economic goods **b :** an organism requiring com[]plex organic compounds for food which it obtains by preying on oth[er] organisms or by eating particles of organic matter — compare PRODUCER 4 — **con·sum·er·ship** \-ˌship\ *n*

consumer credit *n* (1927) **:** credit granted to an individual esp. to [fi]nance the purchase of consumer goods or to defray personal expens[es]

consumer goods *n pl* (1890) **:** goods that directly satisfy human wan[ts]

con·sum·er·ism \kən-ˈsü-mə-ˌri-zəm\ *n* (1944) **1 :** the promotion of [the] consumer's interests **2 :** the theory that an increasing consumption [of] goods is economically desirable; *also* **:** a preoccupation with and an [in]clination toward the buying of consumer goods — **con·sum·er·[ist]** \-rist\ *n* — **con·sum·er·is·tic** \kən-ˌsü-mə-ˈris-tik\ *adj*

consumer price index *n* (1948) **:** an index measuring the change in [the] cost of typical wage-earner purchases of goods and services express[ed] as a percentage of the cost of these same goods and services in som[e] base period — called also *cost-of-living index*

con·sum·ing \kən-ˈsü-miŋ\ *adj* (1920) **:** deeply felt **:** ARDENT ⟨a ~ [in]terest⟩; *also* **:** ENGROSSING

[1]**con·sum·mate** \ˈkän(t)-sə-mət, kən-ˈsə-mət\ *adj* [ME *consummat* fu[l]filled, fr. L *consummatus,* pp. of *consummare* to sum up, finish, fr. *com-* + *summa* sum] (1527) **1 :** complete in every detail **:** PERFECT **2 :** extremely skilled and accomplished ⟨a ~ liar⟩ **3 :** of the highest degre[e] ⟨~ skill⟩ ⟨~ cruelty⟩ — **con·sum·mate·ly** *adv*

[2]**con·sum·mate** \ˈkän(t)-sə-ˌmāt\ *vb* **-mat·ed; -mat·ing** *vt* (1530) **1** [a] **:** FINISH, COMPLETE ⟨~ a business deal⟩ **b :** to make perfect **:** ACHIEVE **2 :** to make (marital union) complete by sexual intercou[rse] ⟨~ a marriage⟩ **~** *vi* **:** to become perfected — **con·sum·ma·tiv[e]** \ˈkän(t)-sə-ˌmā-tiv, kən-ˈsə-mə-tiv\ *adj* — **con·sum·ma·tor** \ˈkän(t)-sə-ˌmāt-ər\ *n*

con·sum·ma·tion \ˌkän-sə-ˈmā-shən\ *n* (14c) **1 :** the act of consumma[t]ing ⟨the ~ of a contract by mutual signature⟩; *specif* **:** the consumma[t]ing of a marriage **2 :** the ultimate end **:** FINISH

con·sum·ma·to·ry \kən-ˈsə-mə-ˌtōr-ē, -ˌtȯr-\ *adj* (1648) **1 :** of or rela[t]ing to consummation **:** CONCLUDING **2 :** of, relating to, or being a response or act (as eating or copulating) that terminates a period of us[u.] goal-directed behavior

con·sump·tion \kən-ˈsəm(p)-shən\ *n* [ME *consumpcioun,* fr. [L] *consumption-, consumptio,* fr. *consumere*] (14c) **1 a :** a progressiv[e] wasting away of the body esp. from pulmonary tuberculosis **b :** TUBERCULOSIS **2 :** the act or process of consuming **3 :** the utilization of economic goods in the satisfaction of wants or in the process of production resulting chiefly in their destruction, deterioration, or transformation

[1]**con·sump·tive** \-ˈsəm(p)-tiv\ *adj* (1664) **1 :** tending to consume **2** **:** of, relating to, or affected with consumption — **con·sump·tive·ly** *adv*

[2]**consumptive** *n* (1666) **:** a person affected with consumption

[1]**con·tact** \ˈkän-ˌtakt\ *n* [F or L; F, fr. L *contactus,* fr. *contingere* to hav[e] contact with — more at CONTINGENT] (1626) **1 a :** union or junctio[n] of surfaces **b :** the apparent touching or mutual tangency of the limb[s] of two celestial bodies or of the disk of one body with the shadow of another during an eclipse, transit, or occultation **c (1) :** the junctio[n] of two electrical conductors through which a current passes **(2)** **:** [a] special part made for such a junction **2 a :** ASSOCIATION, RELATIONSHIP **b :** CONNECTION, COMMUNICATION **c :** an establishing of communication with someone or an observing or receiving of a significan[t] signal from a person or object ⟨radar ~ with Mars⟩ **3 :** a person serving as a go-between, messenger, connection, or source of special information ⟨business ~*s*⟩ **4 :** CONTACT LENS

[2]**con·tact** \ˈkän-ˌtakt, kən-ˈ\ *vi* (1834) **:** to make contact **~** *vt* **1 :** to bring into contact **2 a :** to enter or be in contact with **:** JOIN **b :** to get in communication with ⟨~ your local dealer⟩

usage The use of *contact* as a verb, esp. in sense 2b, is accepted as standard by almost all commentators except those who write college handbooks.

[3]**con·tact** \ˈkän-ˌtakt\ *adj* (1859) **:** maintaining, involving, or activated or caused by contact ⟨~ poisons⟩ ⟨~ sports⟩

contact binary *n* (1952) **:** a binary star system in which the two stars are close enough together for material to pass between them

contact hitter *n* (1982) **:** a hitter in baseball who seldom strikes out

contact inhibition *n* (1965) **:** cessation of cellular undulating movements upon contact with other cells with accompanying cessation of cell growth and division

dis·tel·fink \'dish-tᵊl-ˌfiŋk, 'dis-\ *n* [PaG *dischdelfink,* lit., goldfinch, fr. *dischdel* thistle + *fink* finch] (1939) : a traditional Pennsylvania Dutch design motif in the form of a stylized bird

¹**dis·tem·per** \dis-'tem-pər\ *vt* [ME *distempren,* fr. LL *distemperare* to temper badly, fr. L *dis-* + *temperare* to temper] (14c) **1** : to throw out of order **2** *archaic* : DERANGE, UNSETTLE

²**distemper** *n* (ca. 1555) **1** : bad humor or temper **2** : a disordered or abnormal bodily state esp. of quadruped mammals: as **a** : a highly contagious virus disease esp. of dogs that is caused by a paramyxovirus (genus *Morbillivirus*) and is marked by fever, leukopenia, and respiratory, gastrointestinal, and neurological symptoms **b** : STRANGLES **c** : PANLEUKOPENIA **3** : AILMENT, DISORDER ⟨political ~⟩ ⟨intellectual ~*s*⟩ — **dis·tem·per·ate** \-p(ə-)rət\ *adj*

³**distemper** *n* [obs. *distemper,* v., to dilute, mix to produce distemper, fr. ME, fr. MF *destemprer,* fr. L *dis-* + *temperare*] (1632) **1** : a process of painting in which the pigments are mixed with an emulsion of egg yolk, with size, or with white of egg as a vehicle and which is used for painting scenery and murals **2 a** : the paint or the prepared ground used in the distemper process **b** : a painting done in distemper **3** : any of various water-based paints

⁴**distemper** *vt* (ca. 1873) : to paint in or with distemper

dis·tem·per·a·ture \di-'stem-p(ə-)rə-ˌchu̇r, -pə(r)-, -chər, *chiefly Southern* -ˌt(y)u̇(ə)r\ *n* (1531) : a disordered condition

dis·tend \di-'stend\ *vb* [ME, fr. L *distendere,* fr. *dis-* + *tendere* to stretch — more at THIN] *vt* (15c) **1** : EXTEND **2** : to enlarge from internal pressure : SWELL ~ *vi* : to become expanded *syn* see EXPAND

dis·ten·si·ble \-'sten(t)-sə-bəl\ *adj* [*distens-* (fr. L *distensus,* pp. of *distendere*) + *-ible*] (ca. 1828) : capable of being distended — **dis·ten·si·bil·i·ty** \-ˌsten(t)-sə-'bi-lə-tē\ *n*

dis·ten·sion *or* **dis·ten·tion** \di-'sten(t)-shən\ *n* [L *distention-, distentio,* fr. *distendere*] (15c) : the act of distending or the state of being distended esp. unduly or abnormally

dis·tich \'dis-(ˌ)tik\ *n* [L *distichon,* fr. Gk, fr. neut. of *distichos* having two rows, fr. *di-* + *stichos* row, verse; akin to Gk *steichein* to go — more at STAIR] (1553) : a strophic unit of two lines

dis·ti·chous \'dis-ti-kəs\ *adj* [LL *distichus,* fr. Gk *distichos*] (ca. 1753) : disposed in two vertical rows ⟨~ leaves⟩

dis·till *also* **dis·til** \di-'stil\ *vb* **dis·tilled; dis·till·ing** [ME *distillen,* fr. MF *distiller,* fr. LL *distillare,* alter. of L *destillare,* fr. *de-* + *stillare* to drip, fr. *stilla* drop] *vt* (14c) **1** : to let fall, exude, or precipitate in drops or in a wet mist **2 a** : to subject to or transform by distillation **b** : to obtain by or as if by distillation **c** : to extract the essence of : CONCENTRATE ~ *vi* **1 a** : to fall or materialize in drops or in a fine moisture **b** : to appear slowly or in small quantities at a time **2 a** : to undergo distillation **b** : to perform distillation

dis·til·late \'dis-tə-ˌlāt, -lət; di-'sti-lət\ *n* (ca. 1859) **1** : a liquid product condensed from vapor during distillation **2** : something concentrated or extracted as if by distilling

dis·til·la·tion \ˌdis-tə-'lā-shən\ *n* (14c) **1 a** : the process of purifying a liquid by successive evaporation and condensation **b** : a process like distillation; *also* : an instance of distilling **2** : something distilled : DISTILLATE 2

dis·till·er \di-'sti-lər\ *n* (1577) : one that distills esp. alcoholic liquors

dis·till·ery \di-'sti-lə-rē, -'stil-rē\ *n, pl* **-er·ies** (1759) : the works where distilling (as of alcoholic liquors) is done

dis·tinct \di-'stiŋ(k)t\ *adj* [ME, fr. MF, fr. L *distinctus,* fr. pp. of *distinguere*] (14c) **1** : distinguishable to the eye or mind as discrete : SEPARATE ⟨a ~ cultural group⟩ **2** : presenting a clear unmistakable impression ⟨a neat ~ handwriting⟩ **3** *archaic* : notably decorated **4 a** : NOTABLE ⟨a ~ contribution to scholarship⟩ **b** : readily and unmistakably apprehended ⟨a ~ possibility⟩ — **dis·tinct·ly** \-'stiŋ(k)-tlē, -'stiŋ-klē\ *adv* — **dis·tinct·ness** \-'stiŋ(k)t-nəs, -'stiŋk-nəs\ *n*

syn DISTINCT, SEPARATE, DISCRETE mean not being each and every one the same. DISTINCT indicates that something is distinguished by the mind or eye as being apart or different from others ⟨two *distinct* versions⟩. SEPARATE often stresses lack of connection or a difference in identity between two things ⟨*separate* rooms⟩. DISCRETE strongly emphasizes individuality and lack of connection ⟨broke the job down into *discrete* stages⟩. *syn* see in addition EVIDENT

dis·tinc·tion \di-'stiŋ(k)-shən\ *n* (13c) **1 a** *archaic* : DIVISION **b** : CLASS 4 **2** : the distinguishing of a difference ⟨without ~ as to race, sex, or religion⟩; *also* : the difference distinguished ⟨the ~ between *imply* and *infer*⟩ **3** : something that distinguishes ⟨regional ~*s*⟩ **4** : the quality or state of being distinguishable **5 a** : the quality or state of being distinguished or worthy ⟨a politician of some ~⟩ **b** : special honor or recognition ⟨took a law degree with ~⟩ ⟨won many ~*s*⟩ **c** : an accomplishment that sets one apart ⟨the ~ of being the oldest to win the title⟩

dis·tinc·tive \di-'stiŋ(k)-tiv\ *adj* (15c) **1 a** : serving to distinguish **b** : having or giving style or distinction **2** : capable of making a segment of utterance different in meaning as well as in sound from an otherwise identical utterance *syn* see CHARACTERISTIC — **dis·tinc·tive·ly** *adv* — **dis·tinc·tive·ness** *n*

dis·tin·gué \ˌdēs-ˌtaŋ-'gā, (ˌ)dis-; di-'staŋ-ˌ\ *adj* [F, fr. pp. of *distinguer*] (1813) : distinguished esp. in manner or bearing

dis·tin·guish \di-'stiŋ-(g)wish\ *vb* [MF *distinguer,* fr. L *distinguere,* lit., to separate by pricking, fr. *dis-* + *-stinguere* (akin to L *instigare* to urge on) — more at STICK] *vt* (1561) **1** : to perceive a difference in : mentally separate ⟨so alike they could not be ~*ed*⟩ **2 a** : to mark as separate or different **b** : to separate into kinds, classes, or categories **c** : to give prominence or distinction to ⟨~*ed* themselves in music⟩ **d** : CHARACTERIZE **3 a** : DISCERN ⟨~*ed* a light in the distance⟩ **b** : to single out : take special notice of ~ *vi* : to perceive a difference — **dis·tin·guish·abil·i·ty** \-ˌstiŋ-(g)wi-shə-'bi-lə-tē\ *n* — **dis·tin·guish·able** \-'stiŋ-(g)wi-shə-bəl\ *adj* — **dis·tin·guish·ably** \-blē\ *adv*

dis·tin·guished *adj* (1714) **1** : marked by eminence, distinction, or excellence **2** : befitting an eminent person *syn* see FAMOUS

Distinguished Conduct Medal *n* (1862) : a British military decoration awarded for distinguished conduct in the field

Distinguished Flying Cross *n* (1918) **1** : a British military decoration awarded for acts of gallantry when flying in operations against an enemy **2** : a U.S. military decoration awarded for heroism or extraordinary achievement while participating in an aerial flight

Distinguished Service Cross *n* (1914) **1** : a British military decoration awarded for distinguished service against the enemy **2** : a U.S. Army decoration awarded for extraordinary heroism during operations against an armed enemy

Distinguished Service Medal *n* (1914) **1** : a British military decoration awarded for distinguished conduct in war **2** : a U.S. military decoration awarded for exceptionally meritorious service to the government in a wartime duty of great responsibility

Distinguished Service Order *n* (1886) : a British military decoration awarded for special services in action

dis·tort \di-'stȯrt\ *vb* [L *distortus,* pp. of *distorquēre,* fr. *dis-* + *torquēre* to twist — more at TORTURE] *vt* (ca. 1586) **1** : to twist out of the true meaning or proportion ⟨~*ed* the facts⟩ **2** : to twist out of a natural, normal, or original shape or condition ⟨a face ~*ed* by pain⟩; *also* : to cause to be perceived unnaturally ⟨the new lights ~*ed* colors⟩ **3** : PERVERT ~ *vi* : to become distorted; *also* : to cause a twisting from the true, natural, or normal *syn* see DEFORM — **dis·tort·er** *n*

dis·tor·tion \di-'stȯr-shən\ *n* (1581) **1** : the act of distorting **2** : the quality or state of being distorted : a product of distorting: as **a** : a lack of proportionality in an image resulting from defects in the optical system **b** : falsified reproduction of an audio or video signal caused by change in the wave form of the original signal — **dis·tor·tion·al** \-shnəl, -shə-nᵊl\ *adj*

¹**dis·tract** \di-'strakt, 'dis-ˌtrakt\ *adj* (14c) *archaic* : INSANE, MAD

²**dis·tract** \di-'strakt\ *vt* [ME, fr. L *distractus,* pp. of *distrahere,* lit., to draw apart, fr. *dis-* + *trahere* to draw] (14c) **1 a** : to turn aside : DIVERT **b** : to draw or direct (as one's attention) to a different object or in different directions at the same time **2** : to stir up or confuse with conflicting emotions or motives *syn* see PUZZLE — **dis·tract·i·bil·i·ty** \-ˌstrak-tə-'bi-lə-tē\ *n* — **dis·tract·ible** *or* **dis·tract·able** \-'strak-tə-bəl\ *adj* — **dis·tract·ing·ly** \-tiŋ-lē\ *adv*

dis·tract·ed *adj* (1590) **1** : maddened or deranged esp. by grief or anxiety **2** : mentally confused, troubled, or remote — **dis·tract·ed·ly** *adv*

dis·trac·tion \di-'strak-shən\ *n* (15c) **1** : the act of distracting or the state of being distracted; *esp* : mental confusion **2** : something that distracts; *esp* : AMUSEMENT — **dis·trac·tive** \-'strak-tiv\ *adj*

dis·train \di-'strān\ *vb* [ME *distreynen,* fr. OF *destreindre,* fr. ML *distringere,* fr. L, to draw apart, detain, fr. *dis-* + *stringere* to bind tight — more at STRAIN] *vt* (14c) **1** : to force or compel to satisfy an obligation by means of a distress **2** : to seize by distress ~ *vi* : to levy a distress — **dis·train·able** \-'strā-nə-bəl\ *adj* — **dis·train·er** \-'strā-nər\ *or* **dis·train·or** \-'strā-nər, -ˌstrā-'nȯr\ *n*

dis·traint \di-'strānt\ *n* [*distrain* + *-t* (as in *constraint*)] (ca. 1736) : the act or action of distraining

dis·trait \di-'strā\ *adj* [ME, fr. OF *destrait,* fr. L *distractus*] (15c) : apprehensively divided or withdrawn in attention : DISTRACTED 2

dis·traite \di-'strāt\ *adj* (15c) : DISTRAIT — used esp. of women

dis·traught \dis-'trȯt\ *adj* [ME, modif. of L *distractus*] (14c) **1** : agitated with doubt or mental conflict **2** : INSANE — **dis·traught·ly** *adv*

¹**dis·tress** \di-'stres\ *n* [ME *destresse,* fr. OF, fr. (assumed) VL *districtia,* fr. L *districtus,* pp. of *distringere*] (13c) **1 a** : seizure and detention of the goods of another as pledge or to obtain satisfaction of a claim by the sale of the goods seized **b** : something that is distrained **2 a** : pain or suffering affecting the body, a bodily part, or the mind : TROUBLE ⟨gastric ~⟩ **b** : a painful situation : MISFORTUNE **3** : a state of danger or desperate need ⟨a ship in ~⟩

syn DISTRESS, SUFFERING, MISERY, AGONY mean the state of being in great trouble. DISTRESS implies an external and usu. temporary cause of great physical or mental strain and stress ⟨the hurricane put everyone in great *distress*⟩. SUFFERING implies conscious endurance of pain or distress ⟨the *suffering* of famine victims⟩. MISERY stresses the unhappiness attending esp. sickness, poverty, or loss ⟨the homeless live with *misery* every day⟩. AGONY suggests pain too intense to be borne ⟨in *agony* over the death of their child⟩.

²**distress** *vt* (14c) **1** : to subject to great strain or difficulties **2** *archaic* : to force or overcome by inflicting pain **3** : to cause to worry or be troubled : UPSET **4** : to mar (as clothing or wood) deliberately to give an effect of age — **dis·tress·ing·ly** \-'stre-siŋ-lē\ *adv*

³**distress** *adj* (1926) **1** : offered for sale at a loss ⟨~ merchandise⟩ **2** : involving distress goods ⟨a ~ sale⟩

dis·tress·ful \di-'stres-fəl\ *adj* (1591) : causing distress : full of distress — **dis·tress·ful·ly** \-fə-lē\ *adv* — **dis·tress·ful·ness** *n*

dis·trib·u·tary \di-'stri-byə-ˌter-ē\ *n, pl* **-tar·ies** (1863) : a river branch flowing away from the main stream

dis·trib·ute \di-'stri-byət, *Brit also* 'dis-tri-ˌbyüt\ *vb* **-ut·ed; -ut·ing** [ME, fr. L *distributus,* pp. of *distribuere,* fr. *dis-* + *tribuere* to allot — more at TRIBUTE] *vt* (15c) **1** : to divide among several or many : APPORTION ⟨~ expenses⟩ **2 a** : to spread out so as to cover something : SCATTER **b** : to give out or deliver esp. to members of a group ⟨~ newspapers⟩ ⟨~ leaflets⟩ **c** : to place or position so as to be properly apportioned over or throughout an area ⟨200 pounds *distributed* on a 6-foot frame⟩ **d** : to use (a term) so as to convey information about every member of the class named ⟨the proposition "all men are mortal" ~*s* "man" but not "mortal"⟩ **3 a** : to divide or separate esp. into kinds **b** : to return the units of (as typeset matter) to storage **4** : to use in or as an operation so as to be mathematically distributive ~ *vi* : to be mathematically distributive ⟨multiplication ~*s* over addition⟩ — **dis·trib·u·tee** \dis-ˌtri-byə-'tē\ *n*

syn DISTRIBUTE, DISPENSE, DIVIDE, DEAL, DOLE OUT mean to give out, usu. in shares, to each member of a group. DISTRIBUTE implies an apportioning by separation of something into parts, units, or amounts ⟨*distributed* food to the needy⟩. DISPENSE suggests the giving of a carefully weighed or measured portion to each of a group according to due or need ⟨*dispensed* wisdom to the students⟩. DIVIDE stresses the separation of a whole into parts and implies that the parts are equal ⟨three charitable groups *divided* the proceeds⟩. DEAL emphasizes the allotment of something piece by piece ⟨*deal* out equipment and

EXHIBIT 15

The

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dic·tion·ar·y

FOURTH EDITION

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Manufactured in the United States of America

of supporters or patrons. **b.** A group served by an organization or institution; a clientele.

con•stit•u•ent (kən-stĭch′o͞o-ənt) *adj.* **1.** Serving as part of a whole; component: *a constituent element.* **2.** Empowered to elect or designate. **3.** Authorized to make or amend a constitution: *a constituent assembly.* ❖ *n.* **1.** A constituent part; a component. See Syns at **element. 2.** A resident of a district or member of a group represented by an elected official. **3.** One that authorizes another to act as a representative; a client. **4.** *Grammar* A functional unit of a grammatical construction, as a verb, noun phrase, or clause. [Lat. *cōnstituēns, cōnstituent-*, pr. part. of *cōnstituere*, to set up. See CONSTITUTE.] —**con•stit′u•ent•ly** *adv.*

constituent structure *n. Grammar* An analysis of the constituents of a construction, such as a sentence.

con•sti•tute (kŏn′stĭ-to͞ot′, -tyo͞ot′) *tr.v.* **-tut•ed, -tut•ing, -tutes 1a.** To be the elements or parts of; compose. **b.** To amount to; equal. **2a.** To set up or establish according to law or provision. **b.** To found (an institution, for example). **c.** To enact (a law or regulation). **3.** To appoint to an office, dignity, function, or task; designate. [ME *constituten* < Lat. *cōnstituere, cōnstitūt-*, to set up : *com-*, com- + *statuere*, to set up; see **stā-** in App.] —**con′sti•tut′er, con′sti•tu′tor** *n.*

con•sti•tu•tion (kŏn′stĭ-to͞o′shən, -tyo͞o′-) *n.* **1.** The act or process of composing, setting up, or establishing. **2a.** The composition or structure of something; makeup. **b.** The physical makeup of a person. **3a.** The system of fundamental laws and principles that prescribes the nature, functions, and limits of a government or another institution. **b.** The document recording such a system. **c. Constitution** The fundamental law of the US, framed in 1787, ratified in 1789, and variously amended since.

con•sti•tu•tion•al (kŏn′stĭ-to͞o′shə-nəl, -tyo͞o′-) *adj.* **1.** Of or relating to a constitution: *a constitutional amendment.* **2.** Consistent with, sanctioned by, or permissible according to a constitution. **3.** Established by or operating under a constitution. **4.** Of or proceeding from the basic structure or nature of a person or thing; inherent. **5.** Of or relating to one's physical makeup. ❖ *n.* A walk taken regularly for one's health. —**con′sti•tu′tion•al•ly** *adv.*

con•sti•tu•tion•al•ism (kŏn′stĭ-to͞o′shə-nə-lĭz′əm, -tyo͞o′-) *n.* **1.** Government in which power is distributed and limited by a system of laws that must be obeyed by the rulers. **2a.** A constitutional system of government. **b.** Advocacy of such a system. —**con′sti•tu′tion•al•ist** *n.*

con•sti•tu•tion•al•i•ty (kŏn′stĭ-to͞o′shə-năl′ĭ-tē, -tyo͞o′-) *n.* Accordance with constitutional provisions or principles.

con•sti•tu•tion•al•ize (kŏn′stĭ-to͞o′shə-nə-līz′, -tyo͞o′-) *tr.v.* **-ized, -iz•ing, -iz•es 1.** To provide with or make subject to a constitution. **2.** To incorporate into or sanction under a constitution. —**con′sti•tu′tion•al•i•za′tion** (-lĭ-zā′shən) *n.*

constitutional monarchy *n.* A monarchy in which the powers of the ruler are restricted to those granted under the constitution and laws of the nation.

con•sti•tu•tive (kŏn′stĭ-to͞o′tĭv, -tyo͞o′-) *adj.* **1.** Making a thing what it is; essential. **2.** Having power to institute, establish, or enact. —**con′sti•tu′tive•ly** *adv.*

con•strain (kən-strān′) *tr.v.* **-strained, -strain•ing, -strains 1.** To compel by physical, moral, or circumstantial force; oblige: *felt constrained to object.* **2.** To keep within close bounds; confine. **3.** To inhibit or restrain; hold back. **4.** To produce in a forced or inhibited manner. [ME *constreinen* < OFr. *constraindre, constraign-* < Lat. *cōnstringere*, to restrain, compress : *com-*, com- + *stringere*, to bind, press together.] —**con•strain′a•ble** *adj.* —**con•strain′ed•ly** (-strā′nĭd-lē) *adv.* —**con•strain′er** *n.*

con•straint (kən-strānt′) *n.* **1.** The threat or use of force to prevent, restrict, or dictate the action or thought of others. **2.** The state of being restricted or confined within prescribed bounds. **3.** One that restricts, limits, or regulates; a check: *moral constraints.* **4.** Embarrassed reserve or reticence; awkwardness. [ME *constreinte* < OFr. < fem. p. part. of *constraindre*, to constrain. See CONSTRAIN.]

con•strict (kən-strĭkt′) *v.* **-strict•ed, -strict•ing, -stricts** —*tr.* **1.** To make smaller or narrower by binding or squeezing. **2.** To squeeze or compress. **3.** To restrict the scope or freedom of; cramp. —*intr.* To become constricted. [Lat. *cōnstringere, cōnstrict-*, to compress. See CONSTRAIN.] —**con•stric′tive** *adj.* —**con•stric′tive•ly** *adv.*

con•stric•tion (kən-strĭk′shən) *n.* **1a.** The act or process of constricting. **b.** The condition or result of being constricted. **c.** Something that constricts. **2.** A feeling of tightness or pressure. **3.** A constricted or narrow part.

con•stric•tor (kən-strĭk′tər) *n.* **1.** One that constricts, as a muscle that compresses a part of the body. **2.** Any of various snakes that tightly coil around and asphyxiate their prey.

con•stringe (kən-strĭnj′) *tr.v.* **-stringed, -string•ing, -string•es** To cause to contract; constrict. [Lat. *cōnstringere*. See CONSTRAIN.] —**con•strin′gen•cy** *n.* —**con•strin′gent** *adj.*

con•struct (kən-strŭkt′) *tr.v.* **-struct•ed, -struct•ing, -structs 1.** To form by assembling or combining parts; build. **2.** To create (a sentence, for example) by systematically arranging ideas or terms. **3.** *Mathematics* To draw (a geometric figure) that meets specific requirements. ❖ *n.* (kŏn′strŭkt′) **1.** Something formed or constructed from parts. **2a.** A concept, model, or schematic idea. **b.** A concrete image or idea. [Lat. *cōnstruere, cōnstrūct-* : *com-*, com- + *struere*, to pile up.] —**con•struct′i•ble** *adj.* —**con•struc′tor, con•struct′er** *n.*

con•struc•tion (kən-strŭk′shən) *n.* **1a.** The act or process of constructing. **b.** The art, trade, or work of building. **2a.** A structure, such as a building. **b.** Something fashioned or devised systematically. **c.** An artistic composition using various materials; an assemblage or a collage. **3.** The way in which something is built or put together. **4.** The interpretation or explanation given to an expression or a statement. **5.** *Grammar* **a.** The arrangement of words in a meaningful phrase, clause, or sentence. **b.** A group of words so arranged. —**con•struc′tion•al** *adj.* —**con•struc′tion•al•ly** *adv.*

con•struc•tion•ist (kən-strŭk′shə-nĭst) *n.* A person who construes a legal text or document in a specified way.

construction paper *n.* A heavy paper produced in a variety of colors and used in artwork esp. for folded and cutout designs.

con•struc•tive (kən-strŭk′tĭv) *adj.* **1.** Serving to improve or advance; helpful. **2.** Of or relating to construction; structural. **3.** *Law* Based on an interpretation; not directly expressed. —**con•struc′tive•ly** *adv.* —**con•struc′tive•ness** *n.*

con•struc•tiv•ism (kən-strŭk′tə-vĭz′əm) *n.* A movement in modern art originating in Moscow in 1920 and characterized by the use of industrial materials to create nonrepresentational, often geometric objects. —**con•struc′tiv•ist** *n.*

con•strue (kən-stro͞o′) *v.* **-strued, -stru•ing, -strues** —*tr.* **1.** To adduce or explain the meaning of; interpret. **2.** *Grammar* **a.** To analyze the structure of (a clause or sentence). **b.** To use syntactically: *The noun* fish *can be construed as singular or plural.* **3.** To translate, esp. aloud. —*intr.* **1.** To analyze grammatical structure. **2.** To be subject to grammatical analysis. ❖ *n.* (kŏn′stro͞o′) An interpretation or translation. [ME *construen* < LLat. *cōnstruere* < Lat., to build. See CONSTRUCT.] —**con•stru′al** *n.*

con•sub•stan•tial (kŏn′səb-stăn′shəl) *adj.* Of the same substance, nature, or essence. [ME *consubstancial* < LLat. *cōnsubstantiālis* : Lat. *com-*, com- + LLat. *substantiālis*, substantial; see SUBSTANTIAL.]

con•sub•stan•ti•ate (kŏn′səb-stăn′shē-āt′) *tr. & intr.v.* **-at•ed, -at•ing, -ates** To unite or become united in one common substance, nature, or essence.

con•sub•stan•ti•a•tion (kŏn′səb-stăn′shē-ā′shən) *n.* The doctrine that the substance of the body and blood of Jesus coexists with the substance of the Eucharistic bread and wine.

con•sue•tude (kŏn′swĭ-to͞od′, -tyo͞od′) *n.* Custom; usage. [ME < Lat. *cōnsuētūdō*. See CUSTOM.] —**con′sue•tu′di•nar′y** (-to͞od′n-ĕr′ē, -tyo͞od′-) *adj.*

con•sul (kŏn′səl) *n.* **1.** An official appointed by a government to reside in a foreign country and represent that government's commercial interests and assist its citizens there. **2.** Either of the two chief magistrates of the Roman Republic, elected for a term of one year. **3.** Any of the three chief magistrates of the French Republic from 1799 to 1804. [ME, Roman consul < Lat. *cōnsul*; poss. akin to *cōnsulere*, to take counsel.] —**con′su•lar** (-sə-lər) *adj.* —**con′sul•ship′** *n.*

con•su•late (kŏn′sə-lĭt) *n.* **1.** The residence or official premises of a consul. **2.** The office, term of office, or jurisdiction of a consul. **3.** Government by consuls.

consulate general *n., pl.* **consulates general** The consulate occupied by a consul general.

consul general *n., pl.* **consuls general** A consul of the highest rank serving at a principal location and usu. responsible for other consular offices within a country.

con•sult (kən-sŭlt′) *v.* **-sult•ed, -sult•ing, -sults** —*tr.* **1a.** To seek advice or information of. **b.** To refer to: *consulted a directory.* **2.** To take into account; consider. —*intr.* **1.** To exchange views; confer. **2.** To work or serve as a consultant. ❖ *n.* (kən-sŭlt′, kŏn′sŭlt′) A consultation, esp. one involving physicians. [Fr. *consulter* < Lat. *cōnsultāre*, freq. of *cōnsulere*, to take counsel.] —**con•sult′er** *n.*

con•sul•tan•cy (kən-sŭl′tn-sē) *n., pl.* **-cies 1.** The act or an instance of consulting. **2.** A business or agency offering expert or professional advice in a field. **3.** A position as a consultant.

con•sul•tant (kən-sŭl′tənt) *n.* **1.** One who gives expert or professional advice. **2.** One who consults another. —**con•sul′tant•ship′** *n.*

con•sul•ta•tion (kŏn′səl-tā′shən) *n.* **1.** The act or process of consulting. **2a.** A conference at which advice is given or views are exchanged. **b.** A meeting between physicians to discuss the diagnosis or treatment of a case.

con•sul•ta•tive (kən-sŭl′tə-tĭv) also **con•sul•tive** (-sŭl′tĭv) or **con•sul•ta•to•ry** (-tôr′ē, -tōr′ē) *adj.* Of or relating to consultation; advisory.

con•sul•tor (kən-sŭl′tər) *n. Roman Catholic Church* **1.** A person, such as a priest, appointed to assist and advise a bishop. **2.** An adviser to a congregation of the Curia.

con•sum•a•ble (kən-so͞o′mə-bəl) *adj.* **1.** That can be consumed: *consumable energy.* **2.** That may be depleted or worn out by use. ❖ *n.* A consumable good or service.

con•sume (kən-so͞om′) *v.* **-sumed, -sum•ing, -sumes** —*tr.* **1.** To take in as food; eat or drink up. **2a.** To expend; use up. **b.** To

ă	pat	oi	boy
ā	pay	ou	out
âr	care	o͝o	took
ä	father	o͞o	boot
ĕ	pet	ŭ	cut
ē	be	ûr	urge
ĭ	pit	th	thin
ī	pie	*th*	this
îr	pier	hw	which
ŏ	pot	zh	vision
ō	toe	ə	about, item
ô	paw		

Stress marks:
′ (primary);
′ (secondary), as in
lexicon (lĕk′sĭ-kŏn′)

ing, -pers **1.** To mix (powdered pigments or colors) with water and size. **2.** To paint (a work) in distemper. [ME *distemperen*, to dilute. See DISTEMPER¹.]

dis•tend (dĭ-stĕnd′) *v.* **-tend•ed, -tend•ing, -tends** —*intr.* To swell out or expand from or as if from internal pressure. —*tr.* **1.** To cause to distend; dilate. **2.** To extend. [ME *distenden* < Lat. *distendere* : *dis-*, dis- + *tendere*, to stretch; see **ten-** in App.]

dis•ten•si•ble (dĭ-stĕn′sə-bəl) *adj.* That can be distended: *a fish with a distensible stomach.* —**dis•ten′si•bil′i•ty** *n.*

dis•ten•tion also **dis•ten•sion** (dĭ-stĕn′shən) *n.* The act of distending or the state of being distended. [ME *distensioun* < OFr. < Lat. *distēnsiō*, *distēnsiōn-*, alteration of *distentiō* < *distentus*, p. part. of *distendere*, to distend. See DISTEND.]

dis•tich (dĭs′tĭk) *n.*, *pl.* **-tichs 1.** A unit of verse consisting of two lines, esp. as used in Greek and Latin elegiac poetry. **2.** A rhyming couplet. [Lat. *distichon* < Gk. *distikhon* < neut. of *distikhos*, having two rows or verses : *di-*, two; see DI–¹ + *stikhos*, line of verse; see **steigh-** in App.]

dis•ti•chous (dĭs′tĭ-kəs) *adj. Botany* Arranged in two vertical rows on opposite sides of an axis: *distichous leaves.* [< Lat. *distichus*, having two rows < Gk. *distikhos.* See DISTICH.] —**dis′ti•chous•ly** *adv.*

dis•till also **dis•til** (dĭ-stĭl′) *v.* **-tilled, -till•ing, -tills** also **-tilled, -til•ling, -tils** —*tr.* **1.** To subject (a substance) to distillation. **2.** To separate (a distillate) by distillation. **3.** To increase the concentration of, separate, or purify by or as if by distillation. **4.** To separate or extract the essential elements of. **5.** To exude or give off (matter) in drops or small quantities. —*intr.* **1.** To undergo or be produced by distillation. **2.** To fall or exude in drops or small quantities. [ME *distillen* < OFr. *distiller* < Lat. *distillāre*, var. of *dēstillāre*, to trickle : *dē-*, de- + *stillāre*, to drip (< *stilla*, drop).] —**dis•till′a•ble** *adj.*

dis•til•late (dĭs′tə-lāt′, -lĭt, dĭ-stĭl′ĭt) *n.* **1.** A liquid condensed from vapor in distillation. **2.** A purified form; an essence.

dis•til•la•tion (dĭs′tə-lā′shən) *n.* **1.** The evaporation and subsequent collection of a liquid by condensation as a means of purification. **2.** The extraction of the volatile components of a mixture by the condensation and collection of the vapors that are produced as the mixture is heated. **3.** A distillate.

dis•till•er (dĭ-stĭl′ər) *n.* **1.** One that distills, as a condenser. **2.** One that makes alcoholic liquors by the process of distillation.

dis•till•er•y (dĭ-stĭl′ə-rē) *n.*, *pl.* **-ies** An establishment for distilling, esp. for distilling alcoholic liquors.

dis•tinct (dĭ-stĭngkt′) *adj.* **1.** Readily distinguishable from all others; discrete. **2.** Easily perceived by the senses or intellect; clear. See Syns at **apparent. 3.** Clearly defined; unquestionable: *at a distinct disadvantage.* **4.** Very likely; probable. **5.** Notable: *a distinct honor.* [ME, p. part. of *distincten*, to discern < OFr. *destincter* < Lat. *distīnctus*, p. part. of *distinguere*, to distinguish. See DISTINGUISH.] —**dis•tinct′ly** *adv.* —**dis•tinct′ness** *n.*

dis•tinc•tion (dĭ-stĭngk′shən) *n.* **1.** The act of distinguishing; differentiation. **2.** The condition or fact of being dissimilar or distinct; difference. See Syns at **difference. 3.** A distinguishing factor, attribute, or characteristic. **4a.** Excellence or eminence, as of performance, character, or reputation. **b.** A special feature or quality conferring superiority. **5.** Recognition of achievement or superiority; honor.

dis•tinc•tive (dĭ-stĭngk′tĭv) *adj.* **1.** Serving to identify; distinguishing. **2.** Characteristic or typical. **3.** *Linguistics* Phonemically relevant and capable of conveying a difference in meaning, as nasalization in the initial sound of *mat* versus *bat.* —**dis•tinc′tive•ly** *adv.* —**dis•tinc′tive•ness** *n.*

dis•tin•gué (dē′stăng-gā′, dĭs′-, dĭ-stăng′gā) *adj.* Distinguished in appearance, manner, or bearing. [Fr., p. part. of *distinguer*, to distinguish < OFr. See DISTINGUISH.]

dis•tin•guish (dĭ-stĭng′gwĭsh) *v.* **-guished, -guish•ing, -guish•es** —*tr.* **1.** To perceive as being different or distinct. **2.** To perceive distinctly; discern. **3.** To make noticeable or different; set apart. **4.** To cause (oneself) to be eminent or recognized. —*intr.* To perceive or indicate differences; discriminate: *distinguish between right and wrong.* [Alteration of obsolete *distingue* < ME *distinguen* < OFr. *distinguer* < Lat. *distinguere*, to separate.] —**dis•tin′guish•a•ble** *adj.* —**dis•tin′guish•a•bly** *adv.*

dis•tin•guished (dĭ-stĭng′gwĭsht) *adj.* **1.** Characterized by excellence or distinction; eminent. **2.** Dignified in conduct or appearance.

Distinguished Conduct Medal *n.* A British military decoration for distinguished conduct in the field.

Distinguished Flying Cross *n.* **1.** A US military decoration awarded for heroism or extraordinary achievement in aerial combat. **2.** A British military decoration awarded to officers of the Royal Air Force for extraordinary achievement.

Distinguished Service Cross *n.* **1.** A US Army decoration awarded for exceptional heroism in combat. **2.** A British military decoration awarded to officers of the Royal Navy for gallantry in action.

Distinguished Service Medal *n.* **1.** A US military decoration awarded for distinguished performance in a duty of great responsibility. **2.** A British military decoration awarded to noncommissioned officers and members of the Royal Navy and Royal Marines for distinguished conduct in war.

Distinguished Service Order *n.* A British military decoration for gallantry in action.

dis•tort (dĭ-stôrt′) *tr.v.* **-tort•ed, -tort•ing, -torts 1.** To twist out of a proper or natural relation of parts; misshape. **2.** To give a false or misleading account of; misrepresent. **3.** To cause to work in a twisted or disorderly manner; pervert. [Lat. *distorquēre*, *distort-* : *dis-*, apart; see DIS– + *torquēre*, to twist.] —**dis•tort′er** *n.* —**dis•tor′tive** (-stôr′tĭv) *adj.*

dis•tor•tion (dĭ-stôr′shən) *n.* **1a.** The act or an instance of distorting. **b.** The condition of being distorted. **2.** A statement that twists fact; a misrepresentation. **3.** A change in the shape of an image resulting from imperfections in an optical system, such as a lens. **4.** *Electronics* **a.** An undesired change in the waveform of a signal. **b.** A consequence of such a change, esp. a lack of fidelity in reception or reproduction. **5.** *Psychology* The modification of unconscious impulses into forms acceptable by conscious or dreaming perception. —**dis•tor′tion•al, dis•tor′tion•ar′y** *adj.*

dis•tract (dĭ-străkt′) *tr.v.* **-tract•ed, -tract•ing, -tracts 1.** To cause to turn away from the original focus of attention or interest; divert. **2.** To pull in conflicting emotional directions; unsettle. [ME *distracten* < Lat. *distrahere*, *distract-*, to pull away : *dis-*, apart; see DIS– + *trahere*, to draw.] —**dis•tract′ing•ly** *adv.* —**dis•trac′tive** *adj.*

dis•tract•ed (dĭ-străk′tĭd) *adj.* **1.** Having the attention diverted. **2.** Suffering conflicting emotions; distraught. —**dis•tract′ed•ly** *adv.*

dis•tract•er also **dis•trac•tor** (dĭ-străk′tər) *n.* One of the incorrect answers presented as a choice in a multiple-choice test.

dis•trac•tion (dĭ-străk′shən) *n.* **1.** The act of distracting or the condition of being distracted. **2.** Something, esp. an amusement, that distracts. **3.** Extreme mental or emotional disturbance; obsession: *loved the puppy to distraction.*

dis•train (dĭ-strān′) *v.* **-trained, -train•ing, -trains** *Law* —*tr.* **1.** To seize and hold (property) to compel payment or reparation. **2.** To seize the property of (a person) in order to compel payment of debts. —*intr.* To levy a distress. [ME *distreinen* < OFr. *destreindre*, *destreign-* < Med.Lat. *distringere*, *distrinct-* < Lat., to hinder : *dī-*, *dis-*, apart; see DIS– + *stringere*, to draw tight.] —**dis•train′a•ble** *adj.* —**dis•train′ment** *n.* —**dis•trai′nor, dis•train′er** *n.*

dis•train•ee (dĭs′trā-nē′) *n. Law* One that has been distrained.

dis•traint (dĭ-strānt′) *n. Law* The act or process of distraining; distress. [< DISTRAIN (on the model of such pairs as *constrain*, *constraint*).]

dis•trait (dĭ-strā′) *adj.* Inattentive or preoccupied, esp. because of anxiety. [ME < OFr., p. part. of *distraire*, to distract < Lat. *distrahere.* See DISTRACT.]

dis•traught (dĭ-strôt′) *adj.* **1.** Deeply agitated, as from emotional conflict. **2.** Mad; insane. [ME, alteration of *distract*, p. part. of *distracten*, to distract. See DISTRACT.]

dis•tress (dĭ-strĕs′) *tr.v.* **-tressed, -tress•ing, -tress•es 1.** To cause strain, anxiety, or suffering to. See Syns at **trouble. 2.** To mar or otherwise treat (a fabric, for example) to give the appearance of an antique or of heavy use. **3.** *Archaic* To constrain or overcome by harassment. ❖ *n.* **1.** Anxiety or mental suffering. **2a.** Severe strain resulting from exhaustion or an accident. **b.** Acute physical discomfort. **c.** Physical deterioration caused by hard use over time. **3.** The condition of being in need of immediate help: *a motorist in distress.* [ME *distressen* < OFr. *destresser* < *destresse*, constraint < VLat. **dīstrictia* < Lat. *dīstrictus*, p. part. of *dīstringere*, to hinder. See DISTRAIN.] —**dis•tress′ing•ly** *adv.*

dis•tressed (dĭ-strĕst′) *adj.* **1.** Suffering distress. **2.** Damaged or previously used. **3.** Having been foreclosed and offered for sale, usu. below market value. **4.** Intentionally marred or faded to convey an antique or used look.

dis•tress•ful (dĭ-strĕs′fəl) *adj.* Causing or experiencing distress. —**dis•tress′ful•ly** *adv.* —**dis•tress′ful•ness** *n.*

distress signal *n.* An international signal used by a distressed ship or aircraft to request help.

dis•trib•u•tar•y (dĭ-strĭb′yə-tĕr′ē) *n.*, *pl.* **-ies** A branch of a river that flows away from the main stream.

dis•trib•ute (dĭ-strĭb′yo͞ot) *v.* **-ut•ed, -ut•ing, -utes** —*tr.* **1.** To divide and dispense in portions. **2a.** To supply (goods) to retailers. **b.** To deliver or pass out. **3a.** To spread or diffuse over an area; scatter. **b.** To apportion so as to be evenly spread throughout a given area. **4.** To separate into categories; classify. **5.** *Logic* To use (a term) so as to include all individuals or entities of a given class. —*intr. Mathematics* To be distributive. [ME *distributen* < Lat. *distribuere*, *distribūt-* : *dis-*, apart; see DIS– + *tribuere*, to give; see TRIBUTE.]

SYNONYMS *distribute, divide, dispense, dole, deal, ration* These verbs mean to give out in portions or shares. *Distribute* is the least specific: *The government distributed land to settlers. Divide* implies giving out portions, often equal, on the basis of a plan or purpose: *The estate will be divided among the heirs. Dispense* stresses the careful determination of portions, often according to measurement or weight: *dispensed the medication. Dole*, often followed by *out*, implies careful, usually sparing measurement of portions: *The professor doled out praise to the best students. Deal* implies orderly equitable distribution, often piece by piece: *dealt five cards to each player. Ration* refers to equitable division in lim-

ă	pat	oi	boy
ā	pay	ou	out
âr	care	o͝o	took
ä	father	o͞o	boot
ĕ	pet	ŭ	cut
ē	be	ûr	urge
ĭ	pit	th	thin
ī	pie	*th*	this
îr	pier	hw	which
ŏ	pot	zh	vision
ō	toe	ə	about, item
ô	paw		

Stress marks:
′ (primary);
′ (secondary), as in
lexicon (lĕk′sĭ-kŏn′)

EXHIBIT 16
(filed under seal)

EXHIBIT 17

5177685

SERIAL NUMBER	FILING DATE	CLASS	SUBCLASS	GROUP ART UNIT	EXAMINER
07/569,274	08/09/90	364	443 449	2304	Pipala

JAMES R. DAVIS, NORTH CAMBRIDGE, MA; CHRISTOPHER M. SCHMANDT, MILTON, MA.

CONTINUING DATA*******************
VERIFIED

NONE

FOREIGN/PCT APPLICATIONS**********
VERIFIED

NONE

FOREIGN FILING LICENSE GRANTED 09/22/90

CERTIFICATE
MAR 1 1994
OF CORRECTION

	AS FILED	STATE OR COUNTRY	SHEETS DRWGS	TOTAL CLAIMS	INDEP CLAIMS	FILING FEE RECEIVED	ATTORNEY DOCKET NO.
	→	MA	2	58	1	$	

PASTERNACK
WOLF, GREENFIELD & SACKS, P.C. STEWART
FEDERAL RESERVE PLAZA

AUTOMOBILE NAVIGATION SYSTEM Using Real Time Spoken Driving Instructions

U.S. DEPT. of COMM.- Pat.& TM Office

PARTS OF APPLICATION FILED SEPARATELY

NOTICE OF ALLOWANCE MAILED	PREPARED FOR ISSUE 7-2-92		CLAIMS ALLOWED	
6/30/92	Edward Pipala, Assistant Examiner	Docket Clerk	Total Claims 58	Print Claim 1

ISSUE FEE			DRAWING		
Amount Due $1130.00	Date Paid 9-26-92	PARSHOTAM S. LALL, SUPERVISORY PATENT EXAMINER, ART UNIT 234, Primary Examiner	Sheets Drwg. 3	Figs. Drwg. 5	Print Fig. 1

ISSUE CLASSIFICATION		ISSUE BATCH NUMBER
Class 364	Subclass 443	

Label Area

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Form PTO-436A
Rev. 8/89

CO INED DECLARATION AND POWER C ATTORNEY

'elow named inventor, I hereby declare that:
residence, post office address and citizenship are as stated below next to my name,
believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled AUTOMOBILE NAVIGATION SYSTEM

the specification of which

x is attached hereto.

was filed on as Application

Serial No. and was amended on .

I hereby state that I have review and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s):

(Number)	(Country)	(Day/Month/Year Filed)	Yes	No
(Number)	(Country)	(Day/Month/Year Filed)	Yes	No
(Number)	(Country)	(Day/Month/Year Filed)	Yes	No

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: Sam Pasternack, Esquire

Address all telephone calls to Sam Pasternack, Esq. at telephone no. (617) 227-5020

Address all correspondence to Sam Pasternack, Choate, Hall & Stewart, Exchange Place, 53 State Street, Boston, MA 02109

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patents issued thereon.

Full name of sole or first inventor James Raymond Davis

Inventor's signature Date:

Residence: 140 Elm Street, North Cambridge, MA 02140

Citizenship: United States

Post Office Address: 140 Elm Street, North Cambridge, MA 02140

MIT 00326

Loc 036 #4 A(N)

MAIL ROOM SEP 14 1990 PAT. & TRADEMARK OFF.

In the United States Patent and Trademark Office

Applicant : James Raymond Davis and Christopher M. Schmandt Examiner :
Serial No. : 565,274 Art Unit :
Filed : August 9, 1990
For : Automobile Navigation System

Commissioner of Patents and Trademarks
Washington, D.C. 20231

RECEIVED
SEP 10 1990
APPLICATION DIVISION

Information Disclosure Statement

Sir:

Aspects of the invention have been described in the following sources which were incorporated by reference in the specification and are listed on the attached PTO-1449. Copies are enclosed.

1. "Synthetic speech for real time direction-giving," by C.M. Schmandt and J.R. Davis (*Digest of Technical Papers, International Conference on Consumer Electronics*, Rosemont, Illinois, June 6-9, 1989) is an abstract describing the goals of the research which resulted in the present invention.

2. "Synthetic speech for real time direction-giving," by C.M. Schmandt and J.R. Davis (*IEEE Transactions on Consumer Electronics*, 35(3):649-653, August 1989) is an expansion of the above abstract into a paper. (Kindly note that the publication date for this issue was September 8, 1989, as indicated in the accompanying copy of the certificate of copyright registration.)

3. "The Back Seat Driver: Real time spoken driving instructions," by J.R. Davis and C.M. Schmandt (*Proceedings of the IEEE Vehicle Navigation and Information Systems Conference*, Toronto, Canada, September 1989) describes the strategies employed by the present invention to successfully use speech.

4. "Back Seat Driver: Voice assisted automobile navigation," by J.R. Davis (Ph.D. thesis, Massachusetts Institute of Technology, September 1989) is the most detailed publication describing the present invention to date. The thesis includes a long list of references. Those deemed by the applicants relevant to the present invention as claimed are included on the enclosed PTO-1449 and are discussed below. If the examiner requires further information regarding any of the references cited in the thesis but not included in this Information Disclosure Statement, the applicants will be pleased to provide such.

A short news article on the invention appeared in the July 1990 issue of *Technology Review*. The article, entitled "Terminal Back Seat Driver," is listed on the attached PTO-1449 and a copy of the article is enclosed.

The following references were incorporated and discussed in the the specification. They are listed on the attached PTO-1449 and a copy of each is enclosed.

MIT 00336

1. "CD-ROM Assisted Navigation Systems" by O. Ono, H. Ooe, and M. Sakamoto (*Digest of Technical Papers, IEEE International Conference on Consumer Electronics*, Rosemont, Illinois, June 8–10, 1988) describes the vehicle location system built by NEC Home Electronics, Ltd. which was employed in the working prototypes of the present invention. It is a dead-reckoning position keeping system which uses speed and direction sensors. To compensate for error, it uses map matching on a map database stored on CD-ROM.

2. "Attention, intentions, and the structure of discourse" by B.J. Grosz and C.L. Sidner (*Computational Linguistics*, 12(3):175–204, 1986) describes a discourse theory.

3. "The intonational structuring of discourse" by J. Hirschberg and J. Pierrehumbert (*Proceedings of the Association for Computational Linguistics*, 136–144, July 1986) describes a theory of intonational meaning.

The following references, listed on the attached PTO-1449, relate to further aspects of the present invention as embodied in the working protoype:

1. *Geographic Base File GBDF/DIME: 1980 Technical Documentation* (U.S. Department of Commerce, Data Users Services Division, 1980) describes the DIME format, the basis for the map database of the working prototypes of the present invention.

2. "A formal basis for the heuristic determination of minimum cost paths" by P.E. Hart et al. (*IEEE Transactions on SSC*, 4:100–107, 1968) is the first of many papers which discuss the A* search algorithm on which the route finder of the working prototypes of the present invention is based.

3. "Cellular telephone data communication system and method" by Harry M. O'Sullivan (U.S. Patent 4,697,281) describes the error correcting modem used in a working prototype of one embodiment of the present invention.

4. "A voice interface to a direction giving program" by James R. Davis (Technical Report 2, MIT Media Laboratory Speech Group, April 1988) describes the method of address entering using a cellular telephone keypad employed in one embodiment of the present invention.

The following discussion, summarized primarily from the Davis thesis cited above, examines prior automobile navigation systems. A related survey can be found in "Automated provision of navigation assistance to drivers" by Matthew McGranaghan et al. (*The American Cartographer* 14(2):121-138, 1987). The references cited are included on the enclosed PTO-1449. The undersigned attorney does not currently possess copies of most of these articles, and therefore copies of most are not enclosed. However, at the request of the examiner, copies of any article cited will be obtained and forwarded to the examiner for consideration.

Early application of computers to navigation was intended to reduce traffic congestion by providing route information to drivers. In the Electronic Route Guidance System (ERGS) described in "An electronic route guidance system for highway vehicles," by D.A. Rosen et al. (*IEEE Transactions on Vehicular Technology* VT-19(1):143–152, Feb. 1970), a driver beginning a route finds the intersection closest to the destination, then enters a five letter code word for the intersection. When the vehicle passes over an induction loop sensor in the road, it transmits the destination to a central computer. The computer determines the best route, and relays instructions to the car. This interchange of information occurs at every instrumented intersection. Driving direc-

stated in the present specification, the TIGER format has several improvements over the DIME format, but is still a planar graph representing only physical connectivity. It could be used as the basis of a map database for an automobile navigation system if the extensions discussed in the specification are incorporated.

The Taxi! driving simulator, described in "Taxi! Dynamic cartographic software for training cab drivers" by M. Bosworth and R. Low (Technical report, Hunter College Department of Geology and Geography, (212)-772-4000, 1988 paper presented at the Annual Meeting of the Association of American Geographers) includes the concept of turn resistance, a number from one to ten specifying the difficulty of making a given turn, in its map database.

Neukircher and Zechnall, 1986, describes the features of the map used in the Eva system. This map has better position information than DIME. Points are stored in three dimensions and are accurate to 2.5 meters. Road segments are straight lines, chosen so that a new segment begins at either an intersection or when the change in direction exceeds 30 degrees, or when the distance from the center line exceeds 5 meters. Additional attributes of the roads include height and weight restrictions, location of magnetic anomalies, warnings, landmarks, special objects useful in descriptions (e.g. underpasses), layout of complex intersections, and signs. The map has two levels of detail. The coarse level is used for route finding, and the fine level has more detailed information for position finding. Route finding information includes two values for expected speed (one for normal conditions and a second for times of high density), the expected wait time at segment endpoints, and areas where children are likely to be playing.

The University of Calgary AVL-2000 system uses a map that originated as a Canadian government Area Master File. This format, similar to DIME, also required extensive augmentation, as described in "Digital Map Dependent Functions of Automatic Vehicle Location Systems" by C.B. Harris, L.A. Klesh, E.J. Krawkiwshy, H.S. Karimi, N.S.T. Lee (*IEEE Position and Location Symposium*, pp. 79-87, 1988, IEEE CH2675-7). Link (segment) attributes include distance, expected travel time, safety, scenic value, tolls, "impedience value" [sic], one way limitations, banned turns, road type (over- and under-pass, traffic circles, clover leaf), presence of meridians (divided?), and restricted areas. Harris describes as a "special problem" those "source of destination points which correspond to a street addresses [sic] which do not have a unique node identifier". Either their map representation cannot interpolate addresses along segments, or the route finder is restricted to finding routes to nodes only. Harris also mentions auxiliary road information including landmarks, points of interest, emergency services, commerical establishments, weather conditions, traffic flow, and road characteristics and stresses and importance of being able to update the map database over a communications link while driving.

Most systems have expanded the classification of streets. The ETAK map classification is interstate highway, semi-limited access roads and state highways, arterial, collect, light duty roads, alleys or unpaved roads, high speed ramps and low speed ramps. This rich taxonomy is essential to ETAK for choosing which roads to display (lesser roads are suppressed at larger scales to control detail) and in which colors to display them. The Eva system has a two level taxonomy: *rural*, including motorways

and federal highways with separate directional lanes and without intersections, federal highways, roads wider than six meters, roads four to six meters wide, and others, and *urban*, including divided, through, main, side, and restricted.

These maps have some questionable design decisions on the representation of legal restrictions. The ETAK map has no legal topology at all. It is not intended for route finding. The EVA map apparently encodes restrictions on turning by signs, rather than directly in the network. The Calgary map represents legal topology (one ways, banned turns) as a link attribute instead of in the network topology. It may be that the street network represents only physical topology, with the assumption that legal topology will be equivalent to the physical topology unless specially indicated.

The Back Seat Driver appears to be unique in maintaining separate but equal representations for physical and legal topology. These two topologies should be integrated because legal topology is needed for route finding, and physical topology for route description.

Some navigation systems attempt to give warnings about hazardous conditions. In those systems (Eva, Calgary), the hazards (about slope, width, or curves) are encoded explicitly into the map.

Respectfully submitted,

Sam Pasternack

Sam Pasternack
Registration No. 29,576
Attorney for Applicant

Choate, Hall & Stewart
Exchange Place
53 State Street
Boston, MA 02109
(617) 227-5020

EXHIBIT 18

WordNet 2.1 Browser

File History Options Help

Search Word: consult

Searches for consult: Verb Senses:

The verb consult has 4 senses (first 3 from tagged texts)

1. (15) **consult**, confer with -- (get or ask advice from; "Consult your local broker"; "They had to consult before arriving at a decision")
2. (4) **consult**, refer, look up -- (seek information from; "You should consult the dictionary"; "refer to your notes")
3. (2) confer, confabulate, confab, **consult** -- (have a conference in order to talk something over; "We conferred about a plan of action")
4. **consult** -- (advise professionally; "The professor consults for industry")

Overview of consult

EXHIBIT 19

KIRKLAND & ELLIS LLP

AND AFFILIATED PARTNERSHIPS

200 East Randolph Drive
Chicago, Illinois 60601

Jamal M. Edwards
To Call Writer Directly:
(312) 861-3143
jedwards@kirkland.com

(312) 861-2000

www.kirkland.com

Facsimile:
(312) 861-2200
Dir. Fax: (312) 861-2200

March 2, 2007

Via Electronic Mail

Jacob K. Baron
Proskauer Rose LLP
One International Place
Boston, MA 02110-2600

Re: *MIT v. Harman Int'l Indus., Inc.*, Case No. 05-10990-DPW

Dear Jake:

Pursuant to the February 13, 2007 amended schedule, Harman reasserts and further discloses that the following claims require construction: 1, 7, 21, 23, 35, 45, 52, and 54. Attached to this letter is a claim chart showing Harman's proposed constructions for each of the claims identified above.

Additionally, Harman's disclosure today is based upon the information currently available to Harman regarding the claims MIT has asserted and construed in this litigation. Harman reserves the right to propose constructions for any additional claims either: newly asserted by MIT; or asserted but not previously construed by MIT.

We look forward to reviewing MIT's proposed claim constructions and having a productive conference concerning claim construction issues on March 7, 2007 at your offices in Boston.

Sincerely,

Jamal M. Edwards

JME/jbg

ATTACHMENT

HARMAN'S PROPOSED CLAIM CONSTRUCTIONS
As of March 2, 2007

'685 Patent	Harman's Proposed Constructions	Support for Harman's Proposed Construction
1. An automobile navigation system which produces spoken instructions to direct a driver of an automobile to a destination in real time comprising:	plain and ordinary meaning	
computing apparatus for running and coordinating system processes,	plain and ordinary meaning	
driver input means functionally connected to said computing apparatus for entering data into said computing apparatus, said data including a desired destination,	**driver input means:** This limitation is written in the "means-plus-function" format of Section 112, ¶ 6. The function recited in the claim is "entering data into said computing apparatus, said data including a desired destination." The structures disclosed in the specification for performing this function are (1) a computer keyboard or (2) a cellular telephone keypad. Accordingly, this limitation should be construed as follows: A computer keyboard, a cellular telephone keypad, or equivalent structure, which allows a user to enter data into the navigation system computer, including the desired destination. **functionally connected:** connected in a way that facilitates transmission of information; this need not be a physical connection, but may instead include connection via wireless transmission	Column 24, lines 2-3; Column 24, line 9 Column 24, lines 5-7; Column 28, lines 19-36
a map database functionally connected to said computing apparatus which distinguishes between physical and legal connectivity,	**a map database . . . which distinguishes between physical and legal connectivity:** a data base containing map information that includes separate but equal databases for representing each of physical and legal connectivity, thereby causing the route finder to consider only legal paths; this excludes a map database in which legal connectivity is represented as a link attribute. **physical connectivity:** "Physical connectivity" means "how pieces of pavement connect and whether two segments touch." **legal connectivity:** "Legal connectivity" means "whether one can legally drive onto a physically connected piece of pavement and whether it is legal to travel from one segment to another."	'685 patent at Column 2, lines 12-18; Column 4, lines 64-67; Column 5, lines 6-14; Prosecution History IDS at pp. 8-9. *Harris*, Digital Map Dependent Functions of Automatic Vehicle Location Systems, p. 83 *Pilsak*, EVA-An Electronic Traffic Pilot For Motorists, p. 101 *Ono*, CD-ROM Assisted Navigation System, p. 119 *Elliot*, Route Finding in Street Maps by Computers and People, p. 259 *Neukirchner*, Digital Map Data Bases for Autonomous Vehicle Navigation Systems, p. 320

HARMAN'S PROPOSED CLAIM CONSTRUCTIONS
As of March 2, 2007

		Davis thesis at pp. 2, 48, 55, 58
position sensing apparatus installed in the automobile and functionally connected to said computing apparatus for providing said computing apparatus data for determining the automobile's current position,	plain and ordinary meaning **for determining the automobile's current position:** for the purpose of ascertaining the automobile's current position	Figure 5; Column 11, line 42-Column 13, line 4. Dictionary definition of "determine" is "to conclude or ascertain"
a location system functionally connected to said computing apparatus for accepting data from said position sensing apparatus, for consulting said map database, and for determining the automobile's current position relative to the map database,	plain and ordinary meaning **for accepting data:** for the purpose of taking data **for consulting said map database:** for the purpose of seeking or requesting information from said map database. **for determining the automobile's current position relative to the map database:** for the purpose of ascertaining the automobile's current position, considered in comparative relation to the map database.	Figure 5; Column 11, line 42-Column 13, line 4. Dictionary definition of "accept" is "to take" Dictionary definition of "consult" is "to seek advice or information from" or "to refer to for information" Dictionary definition of "relative" is "considered in relation to something else; comparative."
a route-finder functionally connected to said computing apparatus, for accepting the desired destination from said driver input means and the current position from said location system, for consulting said map database, and for computing a route to the destination,	plain and ordinary meaning **for accepting the desired destination:** for the purpose of taking the desired destination [data] **for accepting the current position:** for the purpose of taking the current position [data] **for consulting said map database:** for the purpose of seeking or requesting information from said map database **for computing a route:** for the purpose of determining or calculating a route.	Dictionary definition of "computing" is "determine by using a computer or calculator." www.dictionary.com
a discourse generator functionally connected to said computing apparatus for accepting the current position from said location system and the route from said route finder, for consulting said map database, and for composing	plain and ordinary meaning The term "discourse" is defined in the claim language itself to mean "instructions and other messages." To the extent the term "discourse" needs further construction, the term should be given its plain and ordinary English dictionary meaning of "verbal expression."	

discourse including instructions and other messages for directing the driver to the destination from the current position.	**for accepting the current position:** for the purpose of taking the current position [data] **for accepting the route:** for the purpose of taking the route **for consulting said map database:** for the purpose of seeking or requesting information from said map database **other messages:** messages which are not instructions (i.e. they do not tell you how to get to your destination) and not warnings or alarms; but are instead notification messages, which depend on data external to the system or automobile (i.e., notifications of new electronic mail).	 Column 28, lines 10-15
a speech generator functionally connected to said discourse generator for generating speech from said discourse provided by said discourse generator, and	**speech generator:** a text-to-speech speech synthesizer or similar device that receives input in the form of generated discourse (text) and creates speech based thereon.	Column 23, lines 39-58; Column 3, lines 46-52.
voice apparatus functionally connected to said speech generator for communicating said speech provided by said speech generator to said driver.	**voice apparatus:** an audio speaker	Column 23, lines 59-61; Figure 1
7. The automobile navigation system of claim 1 wherein said map database comprises a three-dimensional representation of street topology.	**three-dimensional representation of street topology:** locations in the data base are stored as three-dimensional coordinates so that the topology (*e.g.*, slope) of the streets are represented. This limitation requires the three-dimensional representation be part of the map database, and does not cover the use of a GPS or other satellite system for determining altitudinal information.	Column 2, lines 29-30; Column 5, lines 26-38.
21. The automobile navigation system of claim 1 further comprising means for updating said map database.	**means for updating said map database**: This limitation is written in the "means-plus-function" format of Section 112 ¶ 6. The function recited in the claim is "updating ***said*** map database" (*i.e.*, the same map database recited in claim 1). The only structure disclosed in the specification for performing this function is a radio broadcast that continually updates the database. Accordingly, this limitation should be construed as follows: A radio broadcast, or its equivalent, which updates the database on a continuous basis. This limitation does not cover the complete replacement of one database by a second, different database, such as , for example by replacing or entirely erasing and	

HARMAN'S PROPOSED CLAIM CONSTRUCTIONS
As of March 2, 2007

	then rewriting a CDROM, DVD, or memory.	
23. The automobile navigation system of claim 1 wherein the map has minimum accuracy of 10 meters.	plain and ordinary meaning. This claim requires that the map database itself has a minimum accuracy of 10 meters. This claim does not cover systems in which the entire system (in which location accuracy is augmented by GPS or in some other way) achieves such an accuracy despite a map that itself lacks such accuracy.	
35. The automobile navigation system of claim 1 wherein said position sensing apparatus comprises displacement and direction sensors installed in the automobile.	**displacement sensor:** a device that senses the distance that a vehicle has traveled. **direction sensor:** a device that senses the direction in which the vehicle is heading.	Figure 5; Column 11, line 42-Column 13, line 4. Figure 5; Column 11, line 42-Column 13, line 4.
45. The automobile navigation system of claim 1 wherein said discourse generated comprises a long description of an act given substantially before the act is to be performed and a short description given at the time the act is to be performed.	**short description:** is the minimum necessary for the act. It is typically an imperative (*e.g.* Bear left.). **long description**: includes at least some other facts about the action, (i.e, an expression indicating the distance or time until the act is to be performed), and possibly information about the next act. if it is close. Neither the long description nor the short description is a brief description, which consists only of a verb phrase. The short descriptions must be given at the "latest time that still permits the driver to act."	Column 15, lines 31-39. Column 11, lines 37-38.
52. The automobile navigation system of claim 1 wherein said automobile navigation system warns the driver of dangers inferred from knowledge of the road network.	"This claim requires that the warning be the result of dangers ***inferred*** from the road network, in other words, the computer determines road hazards by reasoning about road conditions rather than having them built into the map database. This claim does not cover a system that merely gives warnings about hazardous conditions that are encoded explicitly into the database, as opposed to inferred from the road network.	
54. The automobile navigation system of claim 1 wherein said discourse generator is responsive to a user-model stored in said computing apparatus to customize	**discourse generator is responsive to**: the text of the instructions that are composed by the discourse generator is a function of **user-model stored in the computing apparatus**: user characteristic data stored within the computing apparatus that is specific to a	Column 21, lines 22-59.

discourse to the requirements and preferences of said driver.	particular driver/user including one or more of the requirements or preferences identified at Column 21, lines 22-59.	

EXHIBIT 20

VOLUME 1

PAGES 1 - 301

EXHIBITS D32 - D44

IN THE UNITED STATES DISTRICT COURT

FOR THE DISTRICT OF MASSACHUSETTS

No. 05-10990 DPW

- -

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,

Plaintiffs

vs.

HARMAN INTERNATIONAL INDUSTRIES, INCORPORATED,

Defendants

- -

VIDEOTAPED DEPOSITION OF CHRISTOPHER M. SCHMANDT

Wednesday, February 8, 2006 9:38 a.m

Proskauer Rose LLP

One International Place, Boston, MA 02111

Reporter: Janet M. Konarski, RMR, CRR

LegaLink Boston

320 Congress Street, Boston, MA 02110

(617)542-0039

APPEARANCES:

PROSKAUER ROSE LLP
(By Steven M. Bauer, Esquire,
and Kimberly A. Mottley, Esquire)*
One International Place
Boston, Massachusetts 02110
(617)526-9616
Counsel for the Plaintiff

KIRKLAND & ELLIS LLP
(By Craig D. Leavell, Esquire)
200 East Randolph Drive
Chicago, Illinois 60601
(312)861-2105
Counsel for the Defendant

ALSO PRESENT:
Robert P. Hart, Chief Intellectual Property
Counsel, Harman International
Jason Lachapelle, Videographer
* Not present at all times

Q. If you would turn to Claim 1 for me of your patent, the last three limitations of Claim 1 are discourse generator, a speech generator and a voice apparatus, and there is obviously additional language in there, but can you give me a summary of what is the difference between a discourse generator versus a speech generator versus a voice apparatus?

A. A --

MR. BAUER: Objection. Vague.

A. A discourse generator figures out what to say. That is not a definition of discourse generator. That is what it does functionally. It figures out in some context, subject to some limitations, what to say. It generates output in some form. In the case of Back Seat Driver, this was text. It could be other forms, which goes to a speech generator, which is something that can take that intermediate form and turn it into an audio wave form, which acoustically is speech or close to speech.

And the voice apparatus is some means of presenting that sound, presenting that signal as sound. It involves transduction, presenting that signal as sound so that it can be heard by the driver.

Q. So, in the Back Seat Driver system, the

EXHIBIT 21

UNITED STATES DISTRICT COURT

DISTRICT OF MASSACHUSETTS

---X

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,

Plaintiff,

Civil Action No. 05-10990 DPW

v.

HARMAN INTERNATIONAL INDUSTRIES, INCORPORATED,

Defendants.

HIGHLY CONFIDENTIAL EXPERT REPORT OF RICHARD A. BELGARD

---X

> "a text-to-speech synthesizer or similar device that receives input in the form of generated discourse (text) and creates speech based thereon. This does not include a system in which instructions are stored digitally and retrieved from storage, as opposed to being created."

40. The disclosure in the patent specification has significantly more breadth in its description of the speech generator than Harman's proposed construction. In the specification of the '685 patent, at column 23, lines 42-61, the patent describes that the speech generator in the working prototypes is a "commercial text-to-speech synthesizer" named Dectalk. But, the description also discloses that digitized speech could be used as an alternative. In such as system, as explained in the patent, the digitized speech could be stored on a CD-ROM together with the map database.

41. So, unlike the restricted Harman definition, the patent also discloses an alternative speech generator that does not use text input, and where fragments of instructions are stored digitally and retrieved from storage.

42. Dependent claim 56, a dependent claim that differentiates from claim 1, also makes it clear that the speech generator of claim 1 can use digitized speech, although it allows claim 1 to be broader than just using digitized speech. So, to the extent that Harman's proposed construction precludes portions of instructions that are stored digitally, I believe that it is incorrect.

43. In my opinion, MIT's construction of the speech generator element, namely, "a system capable of receiving output from the discourse generator and converting the output into an electronic signal which will generate speech in the voice apparatus" is a proper interpretation of the element.

<u>Analysis of the Claims Against Harman's Products</u>

44. After determining the meaning of the terms and elements in the claims and the claims themselves, I then compared the claims of the patents to certain Harman products.